NDOT Research Report

Report No. 604-16-803

Prioritization of Wildlife-Vehicle Conflict in Nevada

June 2018

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

Disclaimer

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 604-16-803	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Prioritization of Wildlife-Vehicle Conflict in Nevada		5. Report Date 06/2018 6. Performing Organization Code
7. Author(s) Patricia Cramer, PhD, Chris McGinty, MS		8. Performing Organization Report No.
9. Performing Organization Name and Address Patricia Cramer 264 E 100 North Logan, UT 84321		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Nevada Department of Transportation 1263 South Stewart Street Carson City, NV 89712		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract
In Nevada each year vehicle collisions with wild and domestic-feral animals result in an average of over 500 reported crashes, cost the Nevada public over $19 million in crash costs, and kill an estimated 5,032 wild animals. While Nevada constructed several dozen wildlife mitigation features to help reduce these crashes and provide wildlife connectivity in certain locations, there was a need to prioritize areas for future wildlife and livestock mitigation. This study identified areas of animal-vehicle conflict of highest priority where NDOT can create mitigation alternatives to reduce these collisions and make roads safer for travelers. The researchers identified the top hotspot locations for potential wildlife mitigation using the Getis-Ord Gi* Optimized Hot Spot Analysis tool in ArcGIS. Different priority areas were mapped based on crash data with all animal types, only wildlife, horse crashes, and cattle crashes. Another top 25 priority map was created using GIS modeling of safety and ecological data to identify areas of potential animal-vehicle conflict. These hotspot areas were where wildlife and livestock presence near roads is predicted based on many factors. These maps and other research results were presented to Nevada Department of Transportation (NDOT) with recommendations on how to integrate results into transportation planning and operations. Tables for priority hotspots were generated for the entire state and each NDOT district.

17. Key Words Wildlife, wildlife-vehicle conflict, wildlife-vehicle collisions, animal-vehicle collisions, WVC, AVC, horse, cattle, cow, wildlife mitigation, wildlife crossing structures, wildlife fencing, wildlife fence, Getis-Ord hotspots, hotspot modeling, hot spot		18. Distribution Statement No restrictions. This document is available through the: National Technical Information Service Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 278	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PRIORITIZATION OF WILDLIFE-VEHICLE CONFLICT IN NEVADA
RF # 15Q4-E1-03

FINAL REPORT
to
Nevada Department of Transportation

June 30, 2018

Submitted by

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&

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ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by one or more of the following as noted:

- ☐ American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the **National Cooperative Highway Research Program**,

- ☐ Federal Transit Administration and was conducted in the **Transit Cooperative Research Program**,

- ☐ American Association of State Highway and Transportation Officials, in cooperation with the Federal Motor Carriers Safety Administration, and was conducted in Commercial Truck and Bus Safety Synthesis Program,

- ☐ Federal Aviation Administration and was conducted in Airports Cooperative Research Program,

which is administered by the Transportation Research Board of the National Academies.

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PRIORITIZATION OF WILDLIFE-VEHICLE CONFLICT IN NEVADA

PRELIMINARY DRAFT

FINAL REPORT

Prepared for

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June 2018

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ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

AADT	Annual Average Daily Traffic
AVC	Animal-Vehicle Collision(s). This is a phenomenon that represents animal-related crashes. It is not narrowly defined, and is only referred to either as this phenomenon, or with the word 'crash' following it, meaning reported crashes with animals. It includes wild and domestic-feral animals.
Animal-Vehicle Conflict	In this report the term refers to the potential for animal-vehicle collisions. It encompasses reported crashes, carcasses, and the presence of wild and domestic-feral animals near and on the road that could come in conflict with vehicles. Only a fraction of animal-related crashes is reported, and crashes can occur from interactions with animals but without an actual collision with an animal. This term is used to encompass these many possibilities. It is a newly developing form of referring to AVC.
Carcasses	Animal carcasses found along or in Nevada roadways that have been recorded by Nevada Department of Transportation personnel or others. There are typically far more carcasses than crashes, and even more carcasses that occurred without ever being recorded by personnel.
DOT's	U.S. States' Departments of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GPS	Global Positioning System
Mph	Miles per hour
NDOT	Nevada Department of Transportation
NDOW	Nevada Department of Wildlife
PLANA	Planning and Needs Assessment = early stage of planning for NDOT
WVC	Wildlife-Vehicle Collisions, this can be broadly used to represent the phenomenon of collisions with wild animals. In this report, the acronym is used broadly as the phenomenon, and as an adjective for types of crashes and carcasses, such as 'WVC crashes.'
Wildlife-Vehicle Conflict	The potential for vehicle collisions with wild animals. See Animal-vehicle conflict, above, only this refers specifically to wild animals. It was used broadly to define this project, but as livestock became part of the focus, the term Animal-Vehicle Conflict was more highly used in the report.

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under the Nevada Department of Transportation Project RF # 15Q4-E1-03 by the independent wildlife researcher, Patricia Cramer, PhD, who was the Principal Investigator. Mr. Christopher McGinty, also an independent researcher, was the second author. Dr. Fraser Shilling assisted in the early development of this project. Ms. Ellie Leydsman-McGinty produced geographic information systems (GIS) maps for the study. Ms. Christine Gerrard wrote computer code for the GIS modeling.

The project was performed with the guidance of the Technical Advisory Committee and members of Nevada Department of Transportation (NDOT) and Nevada Department of Wildlife (NDOW). The authors wish to thank the Project Champion, NDOT's Ms. Nova Simpson of NDOT Environmental Services. Ms. Simpson conceived of this project and led its development and completion. The authors also acknowledge other NDOT personnel who dedicated time and effort to this project, including the following: Manju Kumar, Matthew DeMattei, and Ken Chambers of Planning and Research; Chris Young of Environmental Services; Mark Costa in Program Development; P.D. Kiser, Jason Gonzalez, Nick Bacon, and Chris Wright of Safety Engineering; Tara Smaltz of District II, Traffic; Stephanie Snider of Information Technology; Natalie Caffaratti of Roadway Design; and many thanks to Lee Bonner NDOT's Government Relations Coordinator. Within NDOW, the authors would like to thank: Cody Schroeder, Cody McKee, Brian Wakeling, and Chet VanDellen.

EXECUTIVE SUMMARY

Introduction

Each year there are over 500 reported animal-vehicle collision crashes on Nevada Department of Transportation (NDOT) administered roads. These crashes cost Nevadans over 19 million dollars, kill up to 5,032 or more wild animals and livestock, cause dozens of human injuries and at least one human fatality annually. These numbers are higher when the number of wild animals killed are estimated to reflect unreported crashes and given a value of $1,000 each; the estimated annual value of over 21 million dollars is closer to actual numbers. With the risk of animal-vehicle collisions exacting a toll on wildlife and the motoring public, it is important for NDOT to focus efforts to reduce the risk of these collisions, while also providing connectivity for animals to move across the landscape. This study identified areas of animal-vehicle conflict of highest priority where NDOT can create mitigation alternatives to reduce these collisions and make roads safer for travelers.

The overall objective of this study was to collect and analyze data on roads and wildlife to identify the priority locations where wildlife mitigation is needed to reduce the risk of wildlife-vehicle conflict. With the research panel's input, the study's objective was expanded to include horses, cattle, and burros in the analyses, and to identify next steps to continue to plan for and construct mitigation to reduce this conflict. The deliverables included: this report which provides a framework and standard measures to help quantify when mitigation is needed; several different hotspot maps that prioritize vehicle conflict with all animals, hotspot maps with just wildlife, just horses, and just cattle; hotspot maps based on both safety and ecological data; and geo-referenced files to be used in a geographic information systems (GIS) project to assist in transportation long range planning and project development. Within the report there are also sources to refer to for funding opportunities, and a benefit-cost analysis that can be used on established and potential mitigation projects. The report also contains dozens of recommendations for NDOT and Nevada Department of Wildlife (NDOW) to enact to help reduce the risk of animal-vehicle conflict.

Data Analyses and Trends

Data analyses concentrated on crash data because they are collected fairly consistently by traffic safety officers across Nevada and were considered the most accurate database for analyzing the extent of animal-vehicle conflict across time and space. Animal-vehicle conflict represents the potential for animal collisions with vehicles while also including the potential for events where crashes occur but are not recorded, where drivers swerve to avoid animals and collide with other objects, and when animals are near or on the road and pose a potential hazard for motorists. With analyses of existing crash data, this potential for animal-vehicle conflict is predicted based on these reported incidents. The term animal-vehicle collision crash data is used to represent reported crashes that involved livestock and wild animals.

Reported crashes are a fraction of the actual number of collisions with animals. When the crash number is multiplied by correction factors from Utah (Olson 2013) and Virginia (Donaldson and Lafon 2008) that were derived from the number of carcasses collected in these areas, the number of large animals killed is from 5.26 to 9.7 more than reported crashes. These numbers do not account for smaller mammals, birds, or reptiles killed by vehicles. If the larger wild ungulates (hooved animals) are given a value of $1,000 per individual estimated killed (Cramer et al. 2014, Cramer et al. 2016), the estimated value of large wildlife killed is over 1.9 million dollars annually. This brings the value of animal-vehicle collisions in Nevada to over 21 million dollars annually.

Analyses of overall crash data from 2007 through 2016 demonstrated that overall there were decreases in the number of reported crashes (until 2016, which showed an increase) while animal-vehicle collision crashes increased. Across different areas of Nevada animal- vehicle collision crash numbers vary and as a proportion of total crashes. Animal- vehicle collision crashes occur in certain rural counties more often than other areas of the state, Figure 1. Elko County had the greatest number, followed by Lincoln County.

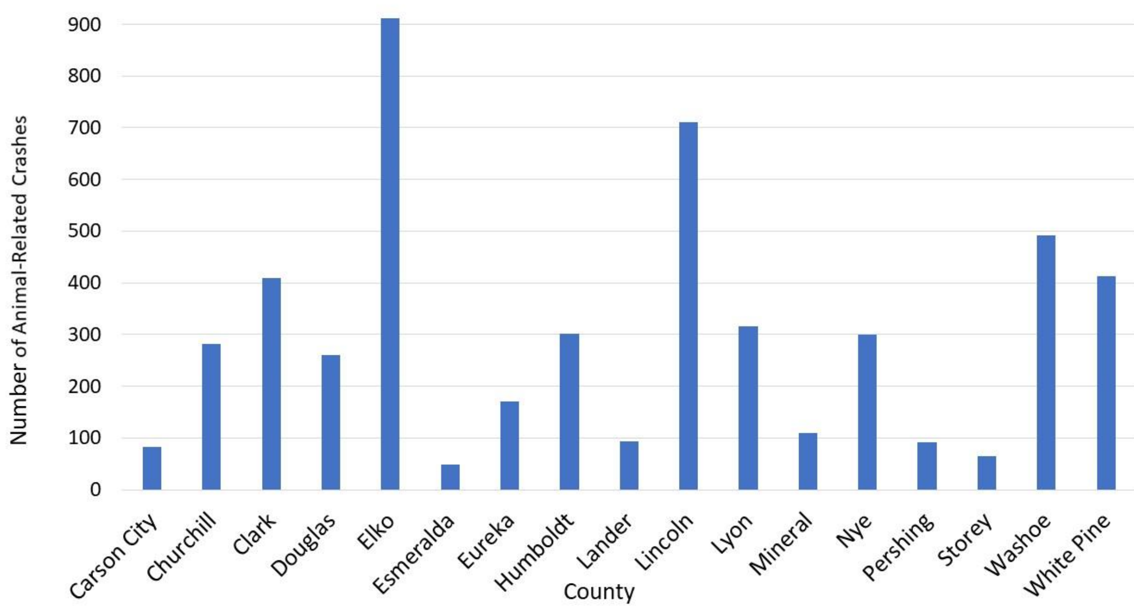


Figure 1. Number of Animal-Related Crashes from 2007-2016 for Nevada Counties.

The number of total reported crashes and animal-vehicle collision crashes for each NDOT District is also very different, Table 1. NDOT District III had 16.2 percent of its crashes reported to involve an animal. This is the district with the least amount of horse and cattle crashes, and the greatest percentage of crashes with wildlife. NDOT District II, the Reno District, had the greatest number of all animal-vehicle collision crashes.

Table 1. Number of Crashes and Animal-Vehicle Collision Crashes per Nevada DOT District, 2006-2015.

Nevada Department of Transportation District	Total Number of Crashes from 2006-2015	Number of Animal-Related Crashes 2006-2015	Percentage of Crashes That Were Animal-Related
District I Las Vegas	153,692	1,478	0.96
District II Reno	47,821	2,083	4.28
District III Elko	9,776	1,591	16.22

Nevada crash reporting forms for law enforcement supply a 14 species pull down menu for officers and deputies to identify the type of animal involved. This proactive data input allows for identification of animals of most concern on roads. While more mule deer are involved in reported crashes in Nevada (an average of 265.5 crashes annually), the horse is the most dangerous animal to motorists. This study was aptly titled 'Wildlife-Vehicle Conflict' but horses, cattle, and burros are among the top six animals involved in animal-vehicle crashes. While the horse is the animal third most often involved in animal-related crashes, with an annual average of 34.8, it has killed more motorist: motorists who hit horses are more than twice as likely to be injured or killed than those that collide with a deer.

Priority Hotspots for Crashes with Animals

The research team modeled animal-vehicle collision crash data to determine priority hotspots across the state for all animals, then only wildlife, horses, and cattle. Half-mile segments of all NDOT administered roads were analyzed with a one-mile search distance for neighboring segment's animal-vehicle collision crashes using the Getis-Ord Statistical Analysis tool in ArcGIS. The hotspots were ranked based on number of crashes per mile over the ten years of data (2007-2016). The resulting 95 and 99 confidence intervals segments were used to determine the top 25 priority hotspots that were considered statistically valid. The priority hotspots for all animal-vehicle collision reported crashes from 2007-2016 became the master map for this study, Figure 2. There were hotspots less than two miles in length. These smaller priority areas were parsed out of this top ranking, for inclusion in another priority hotspot map. The hotspots were due to reported crashes predominantly with the top six species reported, listed in ascending order: mule deer, cattle, horse, dog/coyote, elk, and burros. Crashes with black bear, mountain lion, pronghorn antelope, and bighorn sheep also occurred in several of the hotspots.

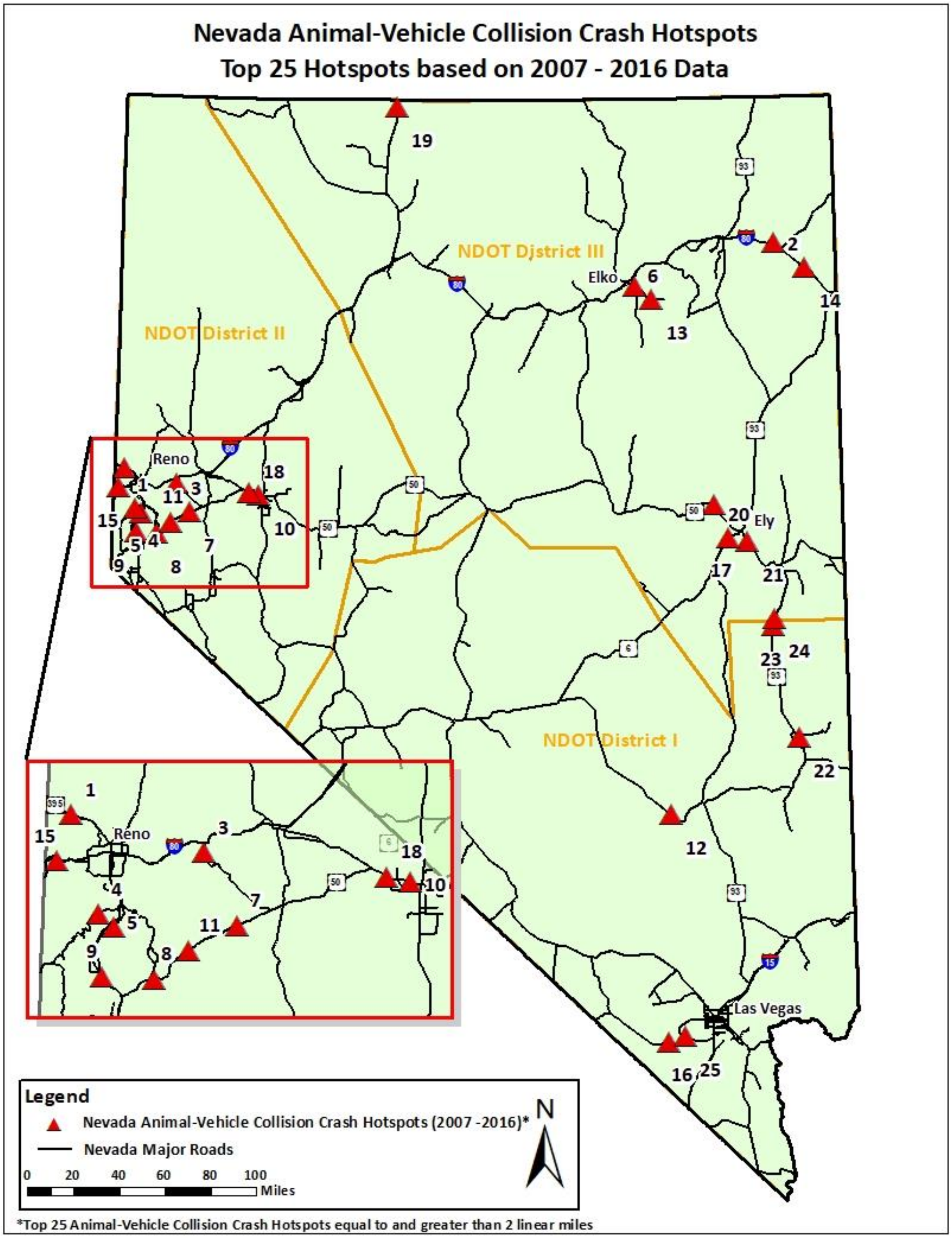


Figure 2. Map of Nevada's Top 25 Priority Reported Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles Long, Based on 2007-2016 Data, Derived From Getis-Ord Analysis 95 Percent and Greater Confidence Intervals.

Table 2 presents the top 25 priority animal-vehicle collision crash hotspots with the name of the road and segment, species involved, and NDOT district it occurs in. The hotspot analysis produced priority segments ranging from one-half a mile to fifteen miles long. Hotspots two miles and longer were included in this list, hotspots less than two miles were tallied in a separate map and list. This allows NDOT to concentrate efforts on larger areas, while also able to consult the smaller areas for different approaches to reduce animal-vehicle collisions in those areas.

Table 2. Description of Animals Involved in Nevada's Top 25 Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles in Length, from 2007-2016 Nevada Department of Transportation Crash Data.

Yellow Shading = NDOT District I	***Green = NDOT District II***	***Pale Blue = NDOT District III***
Rank	**Name**	**Notes on Species, Mitigation, Landscape Factors**
1	US 395 Granite Peak	Mule deer were involved in 55 out of 59 crashes. Dog/coyote were the remaining crashes. Water north of the road may be part of the need for mule deer to move.
2	I-80 Pequop Summit	Two Overpasses, fencing to existing 2 bridges & 2 culverts placed in 2017. 98 percent of crashes were with mule deer.
3	USA Highway Clark Mountain	Horses were involved in 30 of the 34 recorded crashes. Highest priority horse crash hotspot in state.
4	SR 431 Mount Rose Foothills	Mule deer were involved in 42 of 46 crashes. There were 2 horses, and one bear involved in AVC. MM 19 has most crashes, but there is no MM 18 in GIS file, so may be administrative.
5	US 395A Pleasant Valley	Both 395, and I-580. Diversity of species. Number one was mule deer, but there were also 7 horse crashes, 2 cattle, 2 bear, and 1 dog/coyote crash. 395, MM 13 is number 16 horse hotspot, MM 11 is the number 25 hotspot for horses.
6	SR 227 Elko Hills	Out of 34 crashes, deer are listed involved in 24. Two dog/coyote, and 2 cattle crashes. Others unknown or not listed.
7	US 50 Horse Fence End	All 17 reported crashes were with horses. Number 3 horse hotspot.
8	US 50 Dayton	Majority of crashes were horses, Deer crashes = 12; 3 dog/coyote. Number 2 horse crash hotspot. Hotspot includes first mile north on SR 341.
9	I-580 & US 395A South Washoe Lake	Diverse animal species in crashes: Deer= 37, Bear= 3, Coyote/dog = 3, mountain lion= 1. Major wildlife movement linkage from mountains to foothills and water. Number 5 wildlife hotspot.
10	US 50 West Fallon	Deer are 15 out of 19 crash involved animals. Two cattle, 2 dog/coyote crashes. The majority of crashes occurred near the canal on the west side of town, where Coleman and Casey Roads bisect US 50.
11	US 50 Carson Plains	Horses were involved in 12 out of 15 crashes. One deer and 3 dog/coyote crashes were the other animal types.

Yellow Shading = NDOT District I		Green = NDOT District II / Pale Blue = NDOT District III
Rank	**Name**	**Notes on Species, Mitigation, Landscape Factors**
12	SR 375 Tikaboo Valley	Cattle were involved in 24 out of 26 crashes. Top cattle hotspot in the state. One pronghorn. Open Range.
13	SR 227 Spring Creek	South of Elko. Deer crashes were 23 out of 26 crashes. Dog/coyote were 3 crashes.
14	I-80 Silver Zone	Mule deer were involved in 23 of 26 crashes, 1 dog/coyote, 2 elk. A major mule deer migration linkage. Wildlife overpass, and fencing to two bridges placed in 2013.
15	I-80 Stateline to Reno	Out of 90 crashes, mule deer were involved in 72, 4 bear, 4 dog/coyote, 1 cattle, 1 bird, 2 unknown animals. The location is a biodiverse area with mountains, foot hills, and the Truckee River running along the highway.
16	SR 160 Mountain Springs	Of the 26 crashes were the species was identified, 20 = mule deer, 3 = elk, 2 dog/coyote, and 1 burro. NDOT has a wildlife crossing structure schedule to be built at this site in 2019.
17	US 6 Western Eagan Range Foothills	This mountainous area has three ungulate species killed: 1 bighorn sheep, 1 cattle, 5 elk, and 22 mule deer.
18	US 50 Fallon-Ragtown	Of the 32 crashes in the area, 20 were with mule deer. There were 7 dog/coyote and 5 cattle crashes.
19	US 95 Oregon Border	Cattle were involved in 16 out of 17 crashes. One horse. Number 2 cattle hotspot in state
20	US 50 Eagan Range Robinson Summit	The is predominantly a mule deer hotspot: all but one crash were mule deer. The other crash was with an elk.
21	US 6 Steptoe Valley Wildlife Management Area	This hotspot has three ungulate species killed in crashes: 2 pronghorn, 8 elk, and 11 mule deer. This area is tied for the second highest elk hotspot for crashes.
22	US 93 Pioche	Multiple roads in and out of Pioche, entire area a hotspot for mule deer and horses. The area has 3 of the top horse hotspots.
23	US 93 Wambolt Springs	This is the number 1 elk hotspot in the state: out of 26 crashes, 17 were with elk. Deer = 8, cattle = 1.
24	US 93 Travis Reservoir	This area is tied for the second highest elk crash site: 8 elk crashes, deer=3, 1 each of pronghorn antelope, cattle, and dog/coyote.
25	SR 159 Blue Diamond	This is the burro hotspot in the state. Out of 66 crashes in the area, 56 were with burros, deer = 7, 1 dog/coyote, 2 unknown animals. Note this is at the SR 159 and SR 160 intersection.

Crashes with only wildlife were prioritized. The top 25 priority hotspots for wildlife-vehicle collision reported crashes were calculated and mapped over Nevada Department of Wildlife (NDOW) habitat data for mule deer and elk, Figure 3. Table 3 provides precise details where those hotspot locations were by Mile Marker (MM) in each NDOT district. Additional analyses mapped the top 25 hotspots for horse and then cattle related crashes. Those results are presented in the report but are excluded here for brevity's sake.

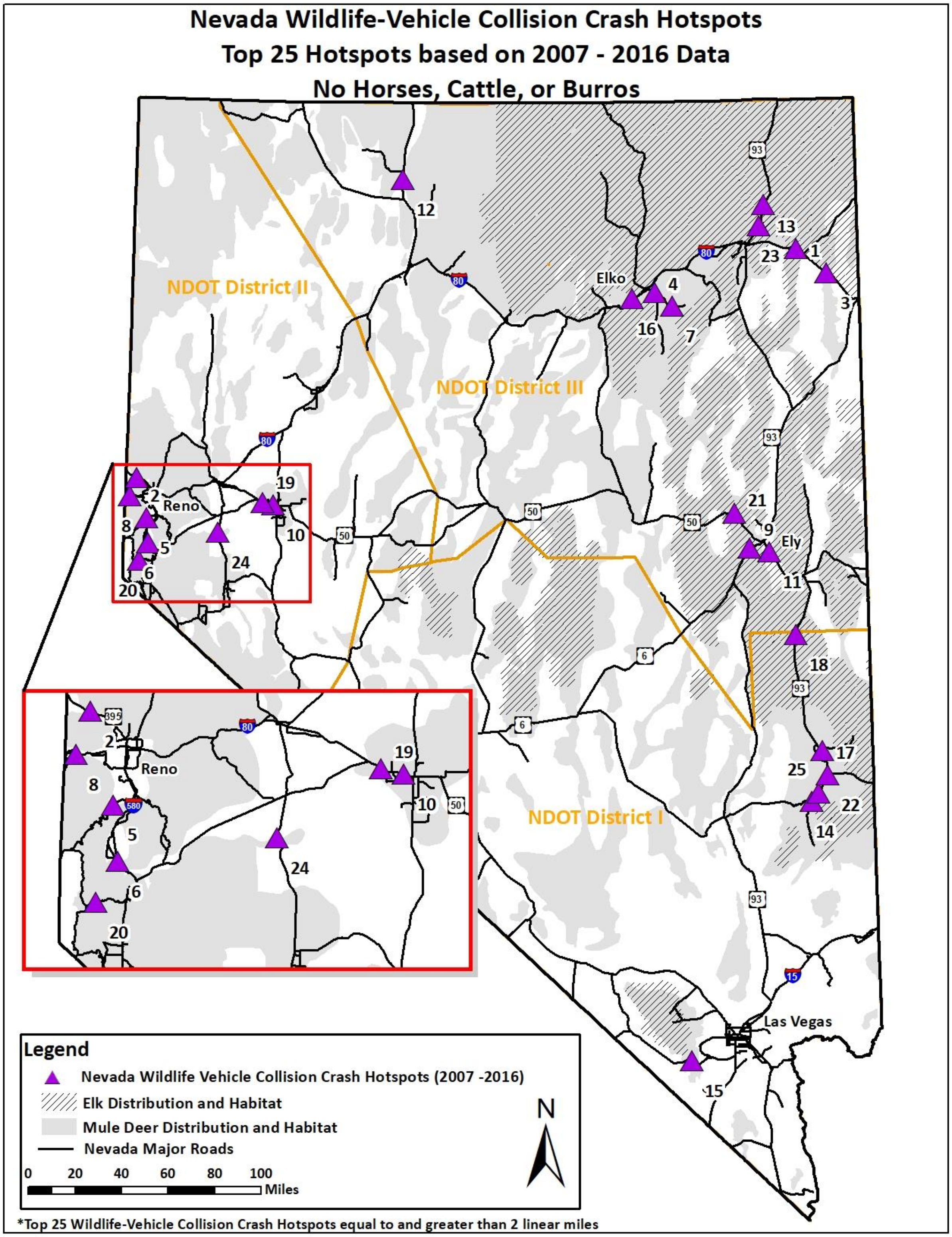


Figure 3. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada 2007-2016, based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros. Hotspots Laid Over Mule Deer and Elk Habitat Maps from Nevada Department of Wildlife.

Table 3. Nevada Top 25 Wildlife-Vehicle Collision Crash Hotspots Greater Than or Equal to Two Miles in Length. Data Taken from Nevada Department of Transportation 2007-2016 Crash Data. Hotspots Created with Getis-Ord Analysis using 95 percent and Great Confidence Intervals.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots.

Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
1	I-80	I-80 Pequop Summit	EL 93.8	EL 99.8	6.07	81	13.34	III
2	US 395A	US 395 Granite Peak	WA 33.5	WA 38.75	5.70	64	11.22	II
3	I-80	I-80 Silver Zone	EL 112.5	EL 115	2.52	21	8.31	III
4	SR 227	SR 227 Elko Hills	EL 1.9	EL 5.9	4.01	32	7.97	III
5	SR 431	SR 431 Mount Rose Foothills	WA 16.9	WA 22.4	5.53	43	7.78	II
6	I-580/US 395A	I-580 & US 395A South Washoe Lake	SR 877 WA 0	SR 877 WA 0.5	6.18	46	11.22	II
			I-580 CC 7.5	I-580 CC 9.2				
			I-580 WA 0	I-580 WA 2.7				
			US 395 WA 0	US 395 WA 2.0				
		Includes all 3 roads on the SW end of Lake Washoe: I-580, US 395A, & SR 877						
7	SR227	SR 227 Spring Creek	EL 12.6	EL 16.1	3.516	26	7.40	III
8	I-80	I-80 Stateline to Reno	SR 647 WA 8.5	SR 647 WA 9.0	12.29	89	7.24	II
			I-580 WA 0.5	I-580 WA 8.5				
			SR 425 WA 2.8	SR 425 WA 6.8				
		West of Reno to California State Line and, includes I-80 Loop = SR 425 in Verdi						
9	US 6	US 6 Western Eagan Range Foothills	WP 28.5	WP 32.5	4.025	28	6.96	III
10	US 50	US 50 West Fallon	CH 17.5	CH 20	2.502	17	6.80	II
11	US 6	US 6 Steptoe Valley Wildlife Management Area	WP 42.5	WP 45.5	3.00	20	6.66	III
12	US 95	US 95 Quinn River Valley	HU 38.5	HU 41.5	3.00	19	6.33	III

Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
13	US 93	US 93 HD Summit	EL 90	EL 96	6.01	37	6.16	III
14	US 93	US 93 Caliente Newman Canyon	LN 91	LN 93	2.01	12	5.97	I
15	SR 160	SR 160 Mountain Springs	CL 18.5	CL 24	5.58	33	5.92	I
16	I-80	I-80 Humboldt River	EL 14.7	EL 17.2	2.54	15	5.90	III
17	US 93 / SR 321	US 93 Pioche	US 93 LN 114	US 93 LN 122.5	15.13	89	5.88	I
			SR 321 LN 0	SR 321 LN 5.1				
			SR 322 LN 0	SR 322 LN 1.75				
			SR 320 LN 10	SR 320 LN 10.5				
		Includes SR 321 and US 93 Intersections with SR 320 & SR 322						
18	US 93	US 93 Wambolt Springs-Travis Reservoir	LN 168.2	LN 173	6.51	38	5.84	I
			WP 0	WP 2				
		All US 93, just crosses two counties						
19	US 50	US 50 Fallon-Ragtown	US 50 CH 12	US 50 CH 15	4.11	24	5.84	II
			SR 117 CH 0	SR 117 CH 1				
		Intersection of US 50 and SR 117						
20	US 50	US 50 Spooner Summit	US 50 DO 11	US 50 DO 14.5	9.64	55	5.71	II
			US 50 CC 0	US 50 CC 5				
			SR 28 DO 0	SR 28 DO 1				
		US 50 in the Mountains west of Carson City, to the intersection with SR 28 and toward Lake Tahoe						
21	US 50	US 50 Eagan Range Robinson Summit	WP 46.7	WP50.2	3.53	20	5.66	III
22	US 93	US 93 Panaca	US 93 LN 104.8	US 93 LN 108	5.34	30	5.62	I
			SR 319 LN 0	SR 319 LN 1				
		US 93 at the Intersection with SR 319 and Southward						

Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
23	US 93	US 93 Ten Mile Summit	EL 82.5	EL 85	2.50	14	5.59	III
24	US 95A	US 95A Stillwater National Wildlife Refuge	LY 34.6	LY 37.3	2.51	14	5.59	II
25	US 93	US 93 Caliente Meadow Valley	LN 95.8	LN 100.9	5.02	28	5.58	I

**** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.***

A goal of this research was to identify hotspots of animal-vehicle CONFLICT. In this report this means areas that animals could become involved in vehicle crashes, not only areas identified as crash hotspots. A second map modeling approach was applied by creating a safety map and an ecological map and then combining them with scores for each half-mile segment of NDOT roads. The safety map layer scored each half mile segment of road based on average annual daily traffic (AADT), percentage of crashes that were animal-related, crash, and carcass data. The ecological map included score card values based on wildlife habitat and corridor maps plus horse and cattle hotspot maps. Each of the two layers was worth 50 points. The map layers were combined for each half mile segment of NDOT administered roads. Each half mile segment of road was ranked with respect to the total tally of points from these two maps. The resulting top 25 hotspots were then considered animal-vehicle conflict hotspots, based on safety and ecological data, Figure 4. Table 4 presents where each of these priority areas are located in Nevada.

This Safety-Ecological Map largely identified areas of potential conflict with wildlife in the eastern mountain ranges of Nevada, and with wildlife and horses in the Reno area of western Nevada, among many other areas. For Nevada to truly address animal-vehicle conflict rather than past crash locations, this map is critical to an overall holistic approach. It is also important to consider these ecological and safety factors in tandem when addressing future mitigation for wildlife and safety. The Safety-Ecological Map of animal-vehicle conflict hotspots may be the most accurate map for predicting where wildlife and livestock mitigation may need to be placed. Crashes do predict the past and to some extent the future, but they fail at predicting where unreported crashes occur, future traffic volumes, new roads, and places where animals cannot get across roads.

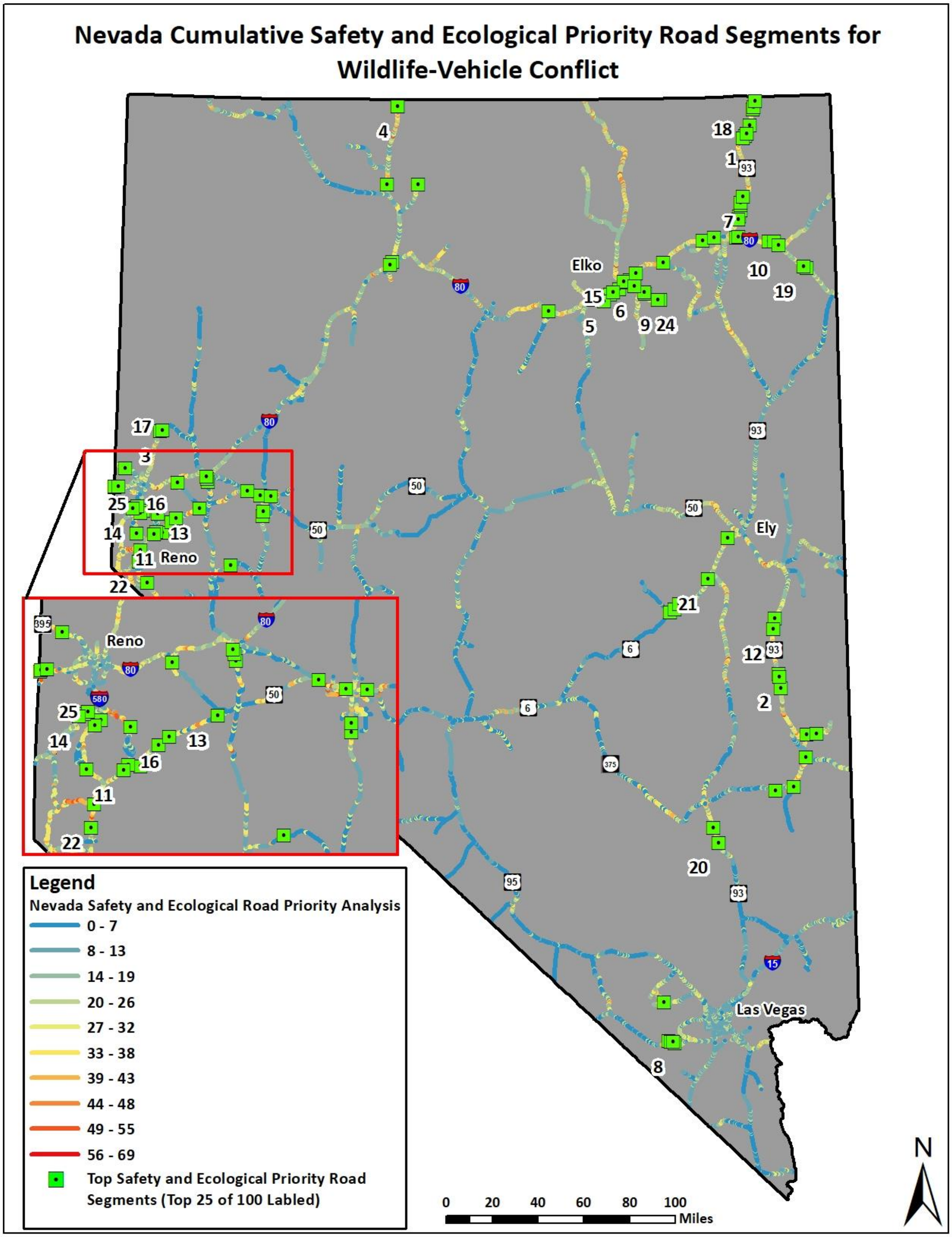


Figure 4. Animal-Vehicle Conflict Top 25 Hotspot Priority Locations Numbered, and Top 100 Locations Represented, Based on Ecological and Safety Data, 2007-2016.

Table 4. Top 25 Hotspots of Animal-Vehicle Conflict Based on Safety and Ecological Data.

Rank	Road	Potential Name = Road, Location, and Mile Marker	Mile Markers*	Length Miles	Safety Value	Ecological Value	Total Points	If in a Getis-Ord Animal-Crash Hotspot, Rank?	District
1	US 93	US 93 Table Top Mountain	US 93 EL 123-126	3.0	32	37	69	No	III
2	US 93	US 93 Fairview Range	US 93 LN 147-148.4	1.4	32	37	67	No	I
3	SR 445	SR 445 Mullen Creek	WA 24.5 - 25	0.5	30	35	65	No	II
4	US 95	US 95 Quinn River Valley	US 95 HU 69 – 71.5	2.5	30	34	64	No	III
5	I-80	I-80 Moleen-Humboldt River	I-80 EL 8 - 12	4.0	48	15	63	No	III
6	SR 227	SR 227 Spring Creek Area	SR 227 EL 2 -6	4.0	38	25	63	No	III
7	US 93	US 93 North of Wells	US 93 EL 94 - 95	1.0	43	20	63	No	III
8	SR 160	SR 160 Mountain Springs	CL 19.7 – 23.3	3.6	43	18	61	16	I
9	SR 227	SR 227 Pleasant Valley	SR 227 EL 17.5 - 18	0.5	36	25	61	0	III
10	I-80	I-80 Pequop Summit	I-80 IR 94 - 100	6.0	36	25	61	2	III
11	US 50	US 50 - SR 341 Intersection	US 50 LY 0 – 5.1 SR 341 LY 0 – 1.1	6.2	49	12	61	8	II
12	US 93	US 93 LI - WP County Line	US 93 LN 169 - 171	2.0	30	30	60	0	I
13	US 50	US 50 Horse Fence End	US 50 LY 24 - 25	1	40	20	60	7	II
14	SR 431	Mt. Rose Highway	WA 18 – 20.3	2.3	40	20	60	4	II
15	I-80	I-80 West Elko	EL 15 - 17	2.0	40	20	60	0	III
16	US 50	US 50 Dayton	US 50 LY 13 – 14.5	1.5	37	22	59	8	III
17	SR 445	SR 445 Mullen Pass	WA 25.5 - 26	0.5	37	22	59	0	II
18	US 93	US 93 Table Top Mountain S	I-80 EL 121.5 - 123	1.5	32	27	59	0	III
19	I-80	I-80 Silver Zone	I-80 IR 113.5 - 117	3.5	39	20	59	14	III
20	US 93	US 93 Pahranagat Valley	LN 31.7 – 32.2	0.5	28	30	58	0	I
21	US 6	US 6 Currant	US 6 WP 9.7 -10.2	0.5	28	30	58	0	I
22	US 395	US 395 Carson River	DO 28.6 - 29.1	0.5	41	17	58	0	II
23	I-80	I-80 Carlin	I-80 EL 4.5 - 7	2.5	38	20	58	0	III
24	SR 227	SR 227 Lamoille	SR 227 EL 16.5 - 17	0.5	33	25	58	0	III
25	SR 431	Mt. Rose - Whites Creek	WA 20.8 – 21.3	5.0	40	17	57	6	II

** Mile Markers Name Abbreviation for County of Occurrence: CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, IR = Iron, LN=Lincoln, LY=Lyon, WA=Washoe, and WP= White Pine.*

The data analyses and mapping allowed comparisons among the NDOT districts and species involved in crashes. NDOT District II had far more of the overall hotspots mapped than any other NDOT district (Table 5). District I have a greater proportion of their hotspot problems due to livestock than other districts. District III is home to predominantly wildlife-vehicle collision crashes. The data analyses revealed specific problem hotspots and types of animal-crash areas that each NDOT district will need to address.

Table 5. Number of Mapped Hotspots for Types of Animal-Vehicle Collision Crashes 2007-2016 per Nevada Department of Transportation District.

	NDOT District		
Type of Hotspots	**I**	**II**	**III**
Animal	5	11	9
Wildlife	6	12	11
Horse	11	10	0
Cattle	9	12	4
Animal-Vehicle Conflict Safety-Ecological Hotspot	5	8	12
Totals per District	36	53	36

Benefit-Cost Analyses

A benefit-cost analysis was performed on nine different stretches of Nevada roads to evaluate if existing and potential wildlife and horse mitigation would be predicted to pay for themselves over time based on past crash and carcass data. The benefit cost equation used was:

$$\text{Benefit/Cost Ratio} = \frac{\text{Annual Potential Benefits x Percentage AVC* Reduction x No. Years Mitigation Lasts}}{\text{Estimated Project Cost + Maintenance Over Time}}$$

* AVC = animal-vehicle collision crashes

The potential benefits were calculated from the severity and cost of past crashes, using both NDOT and Federal Highway Administration (FHWA) values, plus a general value of $1,000 for every wild animal carcass collected in the section of road, all multiplied over time and length of road to give an annual value per mile per year, and an overall benefit value. The costs were the estimated cost of the project plus mitigation over the lifetime of the infrastructure. If the resulting ratio was one or greater, the mitigation would be expected to pay for itself over the time it is expected to last. If the number was less than one, it would not.

Three sections of US 6 near Ely were compared among each other to evaluate which section would have the greatest potential to pay for mitigation over time. The US 6 MM 29-37 west of

Ely is the costliest stretch of the three compared and would be expected to recover the crash costs to society if a mitigation project were constructed at a cost as much as $ 3.80 million. The I-80 Pequop Summit Project was evaluated with both NDOT and FHWA crash values. It would not be expected to pay for itself in 75 years using the NDOT crash values (ratio = 0.77) but would be expected to pay for itself using FHWA crash values (ratio = 1.08). The two wildlife crossing structure mitigation projects on US 93 north of Wells were evaluated: Ten Mile Summit and HD Summit. The Ten Mile Summit project is expected to pay for itself, Nevada benefit-cost ratio = 1.61, FHWA value = 2.97. The HD Summit project is not predicted to pay for itself over 75 years, NDOT benefit-cost ratio = 0.348, and the FHWA benefit-cost = 0.391.

Three horse fencing projects, two of which included horse crossing structures, all east of Carson City were examined with the benefit-cost analysis. The US 50 2013 Horse Mitigation Project from MM 13.75-17.6 is expected to pay for itself in less than 16 years, using NDODT crash values. The US 50 2015 Horse Fencing Project between MM 17.4-20.4, and MM 26.15-29.30 also produced high ratios, NDOT=3.31, FHWA 5.72, and is expected to pay for itself in just over 15 years. The SR 439-USA Highway was newly built and includes over 15 miles of horse exclusion fencing and two horse crossing culverts. A typical benefit-cost analysis cannot be performed on this new highway. Instead, the cost of the mitigation ($2.8 million+), length of the project (15.5 miles), projected reduction in horse-vehicle collisions (90 percent), and length of time the culverts were expected to last (75 years) were used to predict how many crashes the mitigation would need to prevent over time to pay for itself. It is predicted it would need to prevent on average 0.24 crashes per mile per year. Considering the established northern section of the highway is the number one horse-vehicle collision crash hotspot and averages 0.526 horse-vehicle crashes per year, it is very possible this mitigation will pay for itself.

Implementation Plan

The implementation plan for next steps after the completion of this research can be summarized in three main steps: Identify wildlife and livestock-vehicle conflict priority areas; integrate wildlife considerations into planning; and in project development, build, monitor and adaptively manage wildlife mitigation, Figure 5. How the first two steps will be carried out within the scope of NDOT future transportation planning is presented in Figure 6. This plan is intended to create a standardized methodology to be carried out at NDOT headquarters and within the districts. It assigns responsibilities to various divisions within NDOT, districts, and to NDOW.

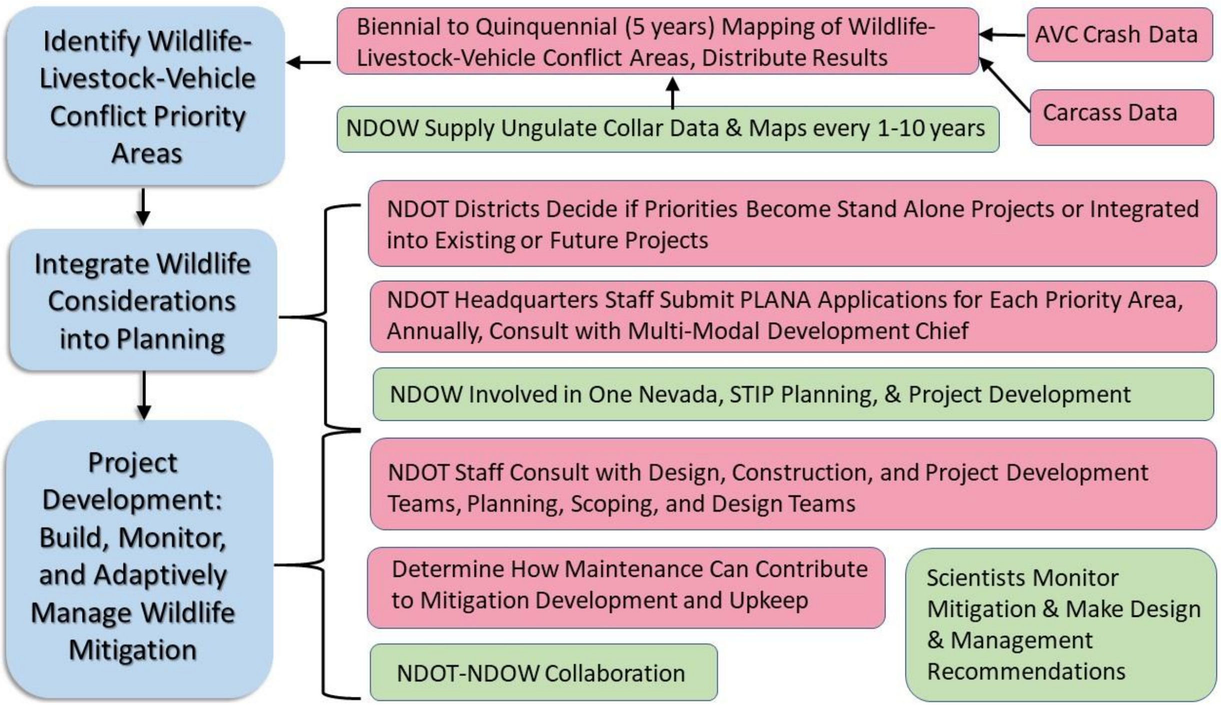


Figure 5. The Three Major Steps for Mitigating Roads for Animal-Vehicle Conflict and the Information and Actions That Support Each Step.

Pink Boxes Represent NDOT Actions, and Green Boxes Represent NDOW Actions. Figure adapted from Cramer et al. 2016.

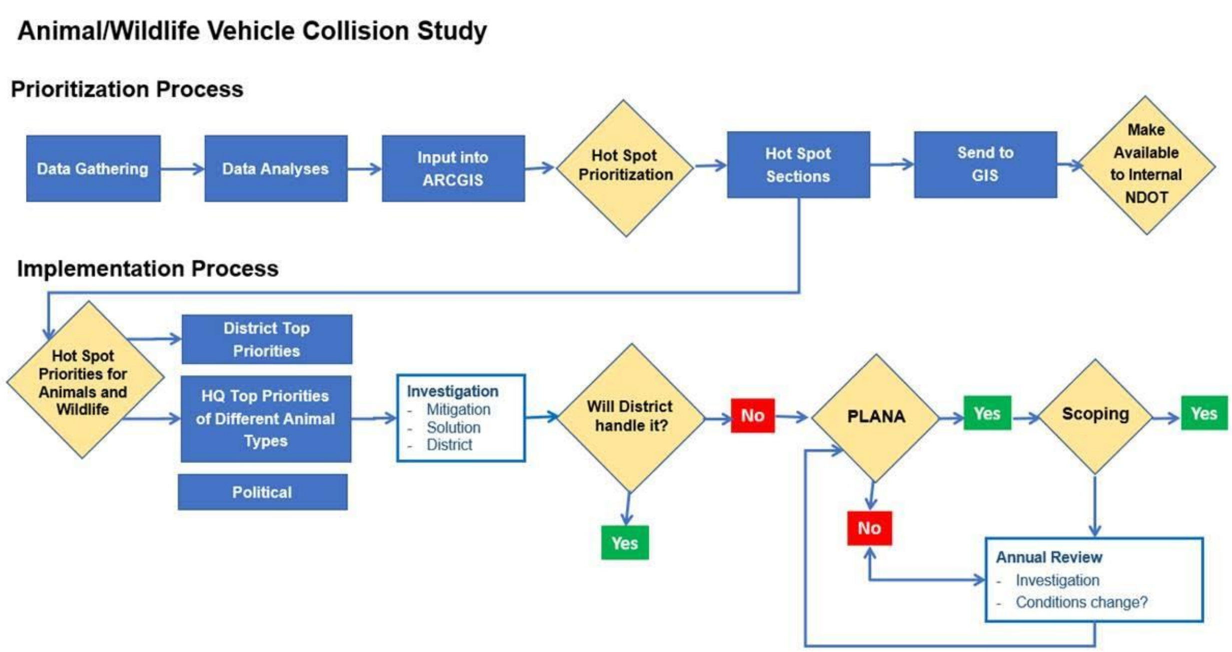


Figure 6. Nevada Department of Transportation Flow Diagram for How Implementation of This Study Could be Incorporated into NDOT Planning Process. Map Courtesy of L. Bonner, NDOT.

Each of the three steps in Figure 5 has several sub-steps that are necessary to complete the major step. These actions are briefly summarized below.

Step 1. Identify the Wildlife-Livestock Vehicle Conflict Priority Areas

The need is to identify locations of animal-vehicle conflicts across the state and within each NDOT district. The type of animals involved require different strategies and approaches, thus the locations, magnitude of the problem, and species involved are all important to identify the top priority areas.

1. Crash Data Management and Analyses – Nevada shall work to establish automatic GPS upload of crash location, and a standardized place and process for pulling crash and carcass data with reference to any animals.
2. Carcass Data Collection, Management, and Analysis – train new maintenance employees at the Maintenance Academy about the importance of carcass data collection, provide an electronic upload of carcass data from the field, convince maintenance personnel, perhaps with promise of punitive actions if not upheld, that carcass data collection and upload are critical components of their positions, and potentially create a public website where the public and county personnel can upload carcass data.
3. NDOW Update Wildlife Habitat Maps and Collar Data Maps – NDOW to upload new maps and empirical GPS collar data to NDOT website for inclusion in project development. Also, NDOT and NDOW should create an annual Animal Safety Summit to work together on identifying and solving animal-vehicle conflict priority areas in Nevada.
4. Conduct Animal- Vehicle Conflict Hotspot Prioritization Process and Make Results Available to NDOT Staff – NDOT will need to assign responsibility of creating future high priority hotspots maps to either the Environmental or Traffic Safety Division. The mapping should be done from every two to every five years, especially just before the development of the five-year plan. The hotspot analyses should be carried out in the same manner this research details. NDOT Environmental should upload all the new data and maps to the NDOT shared GIS portal for personnel to use and notify staff when the products are ready.

Step 2. Integrate Wildlife Considerations Into Planning

The hotspot priority areas where wildlife and livestock are in conflict with traffic along NDOT administered roads will need to be first analyzed by NDOT district staff to investigate potential mitigation solutions. If the district does not handle the steps for potential solutions, the headquarters NDOT staff will need to bring the solutions into the long range state-wide planning process.

1. Districts Decide to Create Stand Alone Animal Mitigation Projects or Integrate Solutions into Existing Projects – NDOT district staff, headed by the environmental staff, annually examines the top animal-vehicle conflict hotspots and decides what areas are to be submitted as standalone projects, and what hotspot solutions could be combined with future or existing projects. These actions can be facilitated with the score card supplied in this report, that can rank priority areas within a district or along a road. The environmental staff also will need to visit each site with a Passage Assessment System (PAS, Kintsch and Cramer 2011) score card to look for potential retrofit solutions. District staff can also look for potential retrofits and solutions that maintenance personnel could address in every day actions. District environmental staff shall also consult NDOW map of collared animal locations within one mile of NDOT administered roads to look for evidence of populations of animals, especially mule deer, moving across the highway of concern, and use this as documentation of the potential conflict.
2. NDOT Headquarters Environmental Staff Submit PLANA Applications for Other Priority Areas – For projects not escorted through the planning process by district staff, headquarters environmental and traffic safety staff shall place remaining hotspots into the Planning and Needs Assessment (PLANA) process as applicants for potential projects. Headquarters' staff shall meet regularly with the Multi-Modal Development Chief and Chief Road Design Engineer to 'shepherd' the potential projects through the NDOT planning process.
3. NDOW Involvement in the Planning Process – NDOT processes shall include at minimum twice yearly meetings with NDOW counterparts at both the headquarters and district levels. These interactions shall be mandated and organized according to a Memorandum of Understanding between the two agencies and fashioned after a similar Idaho agreement (provided in Appendix C).

Step 3. Project Development and Building, Monitoring, and Adaptively Managing Mitigation Solutions

The project development process is where wildlife and livestock mitigation are created and adaptively managed. There are four sub-steps for this phase.

1. NDOT Environmental Staff Consult with Design, Construction, and Project Development Teams – Project development and progress rely on champions, and NDOT environmental staff will need to guide the development of a project over the years it takes to reach fruition. NDOT environmental staff at the headquarters and district levels will need to inform Planning, Scoping, and Design Teams of the needs for such mitigation, past designs, locations of the start and end of hotspots, the problem species and the best mitigation for those species, and other important components of a project.

2. Determine How Maintenance Staff Can Contribute – This includes their involvement from the beginning of planning for a project to the adaptive management phase of a project when small changes will need to be made to adjust infrastructure so it performs optimally in keeping animals off the road and moving beneath or above in wildlife crossing structures.
3. NDOT-NDOW Collaboration – During the project development process and the monitoring and adaptive management phases of mitigation, NDOW should be involved and kept abreast of results. NDOW wildlife biologists have monitored NDOT wildlife mitigation projects in the past and can provide these services and important advice in future projects
4. Scientists Monitor Mitigation and Make Recommendations – Most wildlife and livestock mitigation that involves the building of culverts, bridges, or overpasses should be monitored. Double cattle guards and new designs of escape ramps and fencing should also be monitored to help develop measures with optimum effectiveness. Performance measures can be created with a monitoring project and can be used by the research panel to declare if the mitigation was a success and effective and what needs to be adapted. Continued adaptive management is necessary for most projects and monitoring helps evaluate how effective it is.

The above actions are presented in a systematic manner to help NDOT and NDOW understand how each is part of a greater overall process. Below, some of those recommendations are presented more formally, along with additional actions.

Additional Actions NDOT and NDOW Can Take to Proactively Improve Mitigating Roads for Animals

1. Standardize Biennial to Quinquennial Mapping of Animal-Vehicle Conflict Areas.
2. Create a Memorandum of Understanding between NDOT and NDOW for carcass pick up, data sharing, twice yearly meetings and potentially a wildlife summit, and planning.
3. Create an Electronic Carcass Data Collection System for Use by NDOT and NDOW.
4. NDOT work with NDOW and potentially create a second Memoranda of Agreement – to standardize sharing of data.
5. Standardize Future Nevada Traffic Safety Conferences to include sessions on wildlife and livestock mitigation planning, construction, and research results.
6. In Maintenance Academy Include a Unit on Carcass Data Collection and Reporting.
7. Enlist Nevada Counties to Collect Carcass Data.

Summary and Conclusions

The above actions can be guided in part by the lists of top priority crash and Safety-Ecological segments of NDOT roads. Below, Tables 6, 7, and 8 present the top priority areas for each NDOT district. NDOT personnel at the headquarters' and districts' levels can use these tables to help prioritize actions according to the recommendations above. Future mapping and prioritization processes can update these tables.

Table 6. NDOT District I Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse-Crash Hotspots, Cattle-Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
SR 375 Tikaboo Valley	US 93 LN 10 - 11	US 93 Caliente Newman Canyon	US 93 Newman Canyon	Extra Terrestrial Highway South Tikaboo Valley	US 93 Fairview Range
SR 160 Mountain Springs	SR 375 LN20 - 21	SR 160 Mountain Springs	US 93 North of Pioche	Extra Terrestrial Highway North Tikaboo Valley	SR 160 Mountain Springs
US 93 Pioche	US 93 LN 91.5 - 93.3	US 93 Pioche	US 93 East Pioche	Extra Terrestrial Highway Mid Tikaboo Valley	US 93 Lincoln-White Pine County Line
US 93 Wambolt Springs	US 93 LN 36 - 36.5	US 93 Wambolt Springs-Travis Reservoir	US 93 Caliente Meadow Valley	ARNY 44 Ralston Valley	US 93 Pahranagat Valley
SR 159 Blue Diamond		US 93 Panaca	SR 360 Candelaria Hills	SR 361 North Gabbs	US 6 Currant
		US 93 Caliente Meadow Valley	US 6 SR 360 Intersection	SR 170 Mesquite	
			US 6 Humboldt-Toiyabe National Forest	ARNY 44 Monitor Hills	
			US 6 Mineral Esmerelda County Line	US 95 South Mina	
			US 93 Grassy Springs Pioche	Extra Terrestrial Highway Railroad Valley	
			US 93 North Pioche		
			SR 264 Fish Lake Valley		

Table 7. NDOT District II Crash Hotspots 2007-2016 for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse Collision Crash Spots, Cattle-Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
US 395 Granite Peak	US 95A LY 34.4 - 36	US 395 Granite Peak	USA Parkway I-80 Junction and South	US 50 Lahontan Reservoir	SR 445 Mullen Creek
USA Highway Clark Mountain	US 50 CH 23.2 - 24.3	SR 431 Mount Rose Foothills	US 50 Dayton	US 50A & US 95A South Fernley	US 50 - SR 341 Intersection
SR 431 Mount Rose Foothills	I-580 WA 5.2 - 6.7	I-580 & US 395A South Washoe Lake	US 50 Horse Fence End	SR 270 & 115 South Side of Fallon	US 50 Horse Fence End
US 395A Pleasant Valley	US 50 LY 13 - 14.5	I-80 Stateline to Reno	US 50 Carson Plains	US 50 East Side of Fallon	Mt. Rose Highway
US 50 Horse Fence End	US 50 LY 24 - 25	US 50 West Fallon	US 50A North of Silver Springs	US 95 Walker River	US 50 Dayton
US 50 Dayton	SR 445 WA 24.5 - 26	US 50 Fallon-Ragtown	US 50A South Fernley	SR 400 Dunn Glenn Flat	SR 445 Mullen Pass
I-580/ US 395 South Washoe Lake	SR 118 CH 1.5 - 2	US 50 I-580 West Carson City	US 50 Carson Plains	SR 445 South Pyramid Lake	US 395 Carson River
US 50 West Fallon	SR 659 WA 2.4 - 3	US 95A Stillwater National Wildlife Refuge	SR 341 Virginia City	US 50 & SR 116 Fallon-Harmon Reservoir	Mt. Rose - Whites Creek
US 50 Carson Plains		US 395A Steamboat Hot Springs	SR 341 Steamboat	SR 117 West Edge of Fallon	
I-80 Stateline to Reno		US 95 Walker Lake	Mount Rose Highway	SR 447 East Pyramid Lake	
US 50 Fallon-Ragtown		US 50 & USA Highway Intersection		SR 121 Dixie Valley	

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
		US 395A Pleasant Valley		US 50A & US 95A Wabuska	

Table 8. NDOT District III Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Cattle	Safety and Ecological
I-80 Pequop Summit	I-80 EL 63.5 – 64	I-80 Pequop Summit	US 95 Oregon Border	US 93 Table Top Mountain
SR 227 Elko Hills	I-80 HU 12 - 13.5	I-80 Silver Zone	Grass Valley Road South Winnemucca	US 95 Quinn River Valley
SR 227 Spring Creek	I-80 EU 3 - 3.2	SR 227 Elko Hills	SR 789 Getchel Road-Kelly Creek	I-80 Moleen-Humboldt River
I-80 Silver Zone	US 93 EL 125 - 125.5	SR 227 Spring Creek	I-80 East Winnemucca	SR 227 Spring Creek Area
US 6 Western Eagan Range Foothills	I-80 EU 17.7 - 18.3	US 6 Western Eagan Range Foothills		US 93 North of Wells
US 95 Oregon Border	SR 157 CL 5 - 5.5	US 6 Steptoe Valley Wildlife Management Area		SR 227 Pleasant Valley
US 50 Eagan Range Robinson Summit	US 95 HU 39.5 - 41	US 95 Quinn River Valley		I-80 Pequop Summit
US 6 Steptoe Valley Wildlife Management Area	US 6 WP 56.5 - 58	US 93 HD Summit		I-80 West Elko
US 93 Travis Reservoir	I-80 EL 30 - 31	I-80 Humboldt River		US 93 Table Top Mountain S
	US 93 EL 67.5 - EL 68	US 50 Eagan Range Robinson Summit		I-80 Silver Zone
	US 6 WP 8 - 8.5	US 93 Ten Mile Summit		I-80 Carlin
	US 6 W 8.5 - 10			SR 227 Lamoille

CHAPTER 1. INTRODUCTION AND BACKGROUND

Problem Statement and Research Objective

Every year there are an average of over 500 reported animal-vehicle collision crashes in the state of Nevada. These crashes cost Nevadans over 19 million dollars of damages to vehicles, lost time at work, medical attention and income lost to injuries and death, and many other costs, which are based on Nevada Department of Transportation (NDOT) crash cost estimates. These reported crashes are but a fraction of the actual number. Studies have found carcass numbers of large wild animals found along roads were 5.26 to 9.7 times greater than reported crashes with wild animals (Olson 2013, Donaldson and Lafon 2008). These costs do not include the economic and ecological toll of vehicle-collisions on wildlife populations. With an average of 519 reported crashes with large animals annually, the true numbers of large animals killed range 2,730 to 5,034. These numbers only estimate animals killed on NDOT administered roads, and only animals that die within the road right-of-way. Numbers are predicted to be greater than these for state-wide estimates. In Nevada, animal-vehicle conflict also involves horses, cattle, and burros. With the risk of animal-vehicle collisions exacting a toll on wildlife and the motoring public, it is important NDOT focuses efforts to reduce the risk of these collisions, while also providing movement opportunities for animals to move across the landscape. A state-wide understanding of the animal-vehicle collision and potential conflict areas of highest priority is needed for NDOT to best enact mitigation alternatives to reduce these collisions.

This research builds on Nevada's efforts since 2004 to mitigate transportation corridors for wildlife-vehicle conflict. Those efforts included mapping crash and carcass data, installing mitigation, and researching wildlife crossing structure effectiveness. Earlier hotspot analyses of crash data along Nevada roads helped direct NDOT and Nevada Department of Wildlife (NDOW) efforts to install wildlife crossing structures and fencing in top wildlife-vehicle crash areas (Gibby and Clewell 2006, Wright map 2009). Research on wildlife crossing structures on US 93 helped evaluate the effectiveness of certain structures and inform future designs and maintenance standards (Attah 2012, Simpson 2012, Simpson et al. 2016).

This research is the next phase of Nevada's mitigation of roads for wildlife. It entailed detailed analyses of data related to large wildlife and livestock near roads, crash, carcass, road and traffic data, and wildlife habitat and corridor maps. The data analyses and modeling are reported in repeatable processes that identifies priority locations where wild and domestic animals have been involved in crashes and may be expected to cause future vehicle conflict. This report also provides recommendations on how information about animal-vehicle conflict can be used to inform future NDOT transportation projects in the planning process. The results of this research can assist Nevada in effectively making roads safer for motorists and create additional cost-effective animal mitigation alternatives that would help wildlife populations move below and above roads and persist over time. The research also addressed horse and cattle issues related to motor vehicles on NDOT administered roads.

The overall objective of this study was to collect and analyze existing data on roads, wildlife, and animal-vehicle conflict, identify areas of safety concern along major roads within Nevada, and with the input of the research panel, create a plan that identified needs and priorities associated with the interaction of roadway infrastructure and wildlife movements along major roads within Nevada. The deliverables include usable Geographic Information Systems (GIS) files that highlight animal-vehicle conflict which in turn can be used in future transportation planning, a framework and standard measures Nevada can use to help quantify when wildlife mitigation is needed, and multiple other sources of information that can inform wildlife mitigation funding, research, benefit-cost analyses, and data collection.

Scope of Study

The tasks of this study built upon one another to create a framework and plan for NDOT and partners to follow to address wildlife and livestock-vehicle conflict in the priority areas across Nevada. The tasks were created from the objectives for this project, put forth by NDOT.

In Task 1 (Chapter 2) researchers summarized the current (past 10 years) of statistics related to animal-vehicle collision crashes and carcasses and how they were related to other crashes in Nevada. In the Task 1 chapter, the researchers also reported on how crash and carcass data were collected in Nevada at the time of the report (Appendix A). A literature review and results of informal interviews with colleagues is U.S. western states was also included (Appendix B). An example of the Idaho Memorandum of Understanding between the transportation and wildlife agency concerning wildlife and roads is presented in Appendix C.

In Task 2 (Chapter 3) crash data on wildlife, horses, cattle, and burros were mapped and modeled in GIS. Maps of where six species of wildlife and three species of livestock were reported in crashes and collected as carcasses were presented. The data were modeled using Getis-Ord hotspot analyses to create detailed priority hotspot segments of NDOT administered roads for animal-vehicle collision crashes, wildlife-vehicle collision crashes, horse--vehicle collision crashes, and cattle-vehicle collision crashes. Tables present the priority hotspots for each NDOT district. A second map modeling approach was created by creating a safety map and an ecological map and combining them with scores for each half-mile segment of NDOT roads. This became the animal-vehicle CONFLICT map, based on safety and ecological data. Data used are presented in Appendix D, and methods are detailed in Appendix E.

The Task 3 (Chapter 4) deliverable was a benefit-cost analysis of several wildlife and horse crossing structure mitigation projects and potential future projects. An Excel worksheet was developed for future analyses. A table of all wildlife and horse mitigation projects in Nevada is presented in Appendix F.

In Task 4 (Chapter 5 and GIS geo-databases) the researchers uploaded all geo-referenced GIS files, jpg, data sheets to a NDOT website for inclusion in transportation planning.

In Task 5 (Chapter 6) known traffic volume thresholds and other information from the literature and from the data analyses were used to create a framework with standardized measures for NDOT to consider when planning for wildlife and livestock mitigation.

The Task 6 (Chapter 7) provided a listing and description of potential funding sources and case studies of how other U.S. states used multiple partners in wildlife mitigation projects.

Task 7 (Chapter 8) was the Action and Implementation Plan. This plan provides recommendations for NDOT headquarters and district personnel and NDOW colleagues to carry out to include wildlife and livestock vehicle conflict concerns into overall long term and near term project transportation planning.

Task 8 (Chapter 9) is a wildlife mitigation plan. It summarizes the work performed in this study and gives strategic steps to be carried out to reduce animal-vehicle conflict in Nevada. This chapter can be used as a summary document for the study.

The study is summarized and conclusions are presented in Chapter 10.

CHAPTER 2 SUMMARY OF CURRENT STATISTICS RELATED TO ANIMAL-VEHICLE COLLISIONS IN NEVADA AND LITERATURE REVIEW

Introduction

This chapter first presents previous efforts in Nevada to map wildlife-vehicle collisions (WVC) statewide and the research that examined the effectiveness of two wildlife mitigation projects. Second, analyses of current crash and carcass data are presented, followed by a conclusion and recommendations.

Previous Research on Wildlife-Vehicle Conflict in Nevada

Nevada has been addressing the issue of wildlife-vehicle conflict since the decade previous to the start of this project. Mapping of crash data (Wright, Figure 7), and a 2006 research project by Gibby and Clewell helped Nevada identify the top hot spot areas for WVC and began the process of creating wildlife mitigation projects. Both mapping and crash data endeavors demonstrated that US 93 north of Wells, and I-80 at Pequop Summit were the road segments with the highest deer-vehicle collision numbers in the state. Since then these areas have received four overpass and four underpass wildlife crossing structures. In turn, these mitigation projects were conducted in association with graduate student research on the effectiveness of the crossing structures (Attah 2012, Simpson 2012, Simpson et al. 2016). Additional areas in the state have also received wildlife crossing structures but were not monitored as were the US 93 structures.

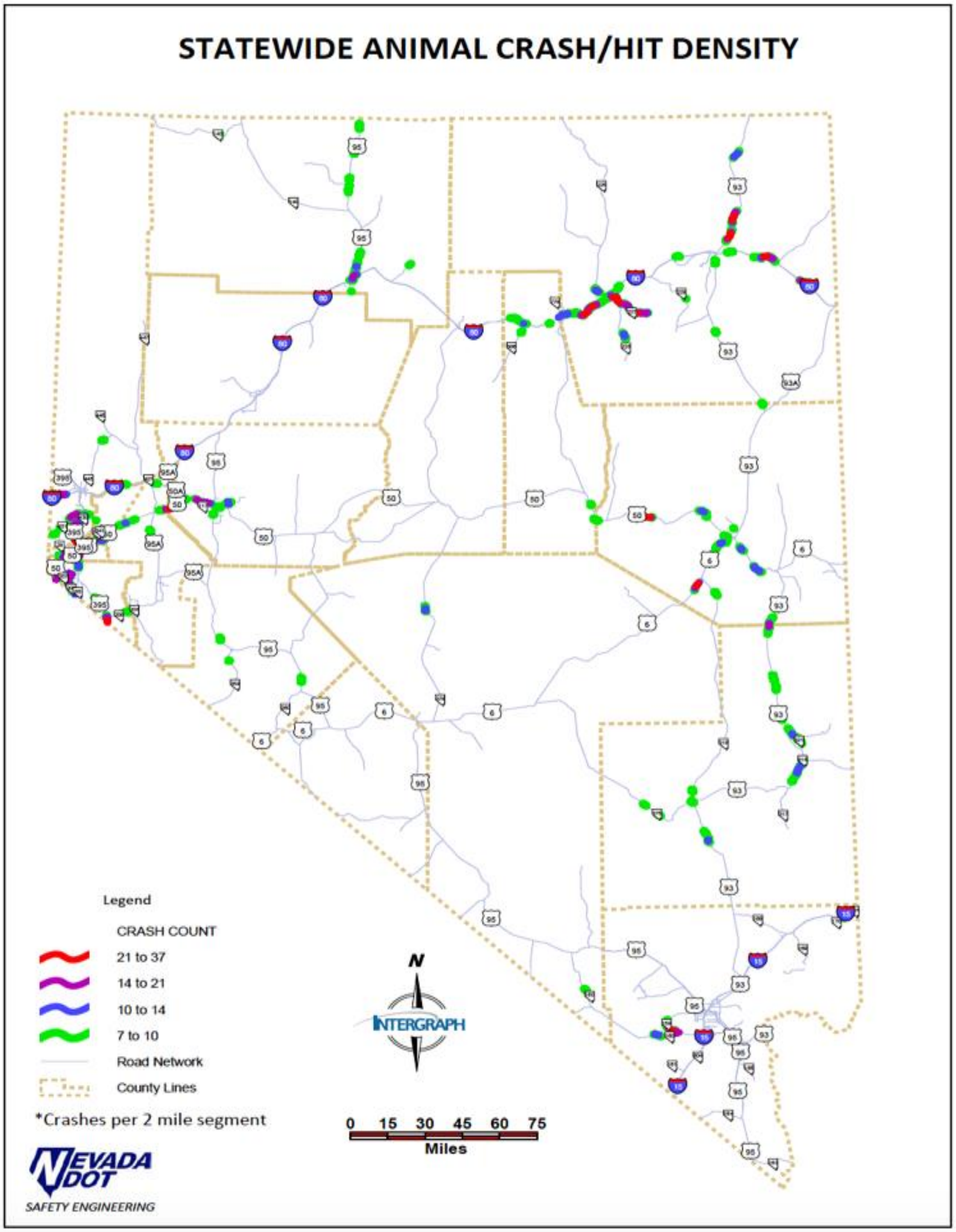


Figure 7. All Crashes Reported to Involve a Wild or Domestic Animal and All Carcasses Reported by NDOT Maintenance 2005-2009. Map Created by Chris Wright of NDOT.
Note: It is presumed this map represents both reported crashes and reported carcasses.

Data Collection Processes and Statistics Related to Wildlife-Vehicle Collisions In Nevada

The researchers reviewed the crash and carcass data collection processes and examined the crash and carcass data for the eleven-year period of 2006-2016.

Overview of NDOT Processes for WVC Crash and Carcass Data Collection and Use

The crash data are collected by safety officers and deputies called to the scene of accidents, and the carcass data are collected by NDOT maintenance personnel. Details of how these data are collected and the forms used can be found in Appendix A, along with information on how the data are transformed into geospatial information to be used in maps. The methods used in analyzing these data are also described in Appendix A.

Results of Crash and Carcass Data Analyses

The 2006 - 2015 crash and carcass data were delivered to the researchers by NDOT personnel in early 2017, and the information was used in this report and in the creation of maps. Original work on this task occurred in the first half of 2017, when the 2016 crash data were unavailable. Two of the seven tables below are calculated on data from 2006- 2015. These include the county animal-related crash data, and the species' specific data. All other tables were updated in late 2017 and include 2007-2016 crash and carcass data.

In Nevada from 2007-2016, there were 5,189 crashes where wild or domestic animals were noted to be involved. This was 2.3 percent of the total crash numbers (224,414). The annual percentage of animal related crashes increased over time through 2015, and dropped slightly in in 2016, Table 9. There was an overall trend of decreasing reported crashes overall, (with a sharp increase in 2016) and a general trend of increasing in animal-related crashes (see Figure 8).

When the ten years of crash and carcass data in Table 9 data are parsed to the first five years (2007-2011), and the second five years (2012-2016), three important trends emerge:

1. The average number of overall crashes decreased, from an annual average of 23,893 to 20,990.
2. Animal related crashes increased from an annual average of 500 to 536.
3. Animal-related crashes as a percent of overall crashes increased from an annual average of 2.1 percent to 2.6 percent.
4. Reported carcasses decreased; carcasses averaged 421 annually in the first five years, and 349 the second half of the 10 years.

Table 9. Number of Total Reported Vehicle Crashes, Crashes Involving a Wild or Domestic Animal, Percentage of Total Crashes That Included an Animal, and Total Carcasses Reported Annually from 2007-2016 on Nevada Department of Transportation Administered Roads.

Year	Total Reported Crashes	Total Reported Crashes Involving Animals	Percentage of Crashes Involving Animals	Total Carcasses of all Animals Reported
2007	26,835	499	1.9	386
2008	25,141	485	1.9	477
2009	23,110	506	2.2	426
2010	22,360	490	2.2	380
2011	22,019	520	2.4	440
2012	21,699	540	2.5	372
2013	21,216	467	2.2	328
2014	18,122	506	2.8	375
2015	19,495	603	3.1	395
2016	24,375	573	2.3	276
Total	224,372	5,189	2.3	3,855

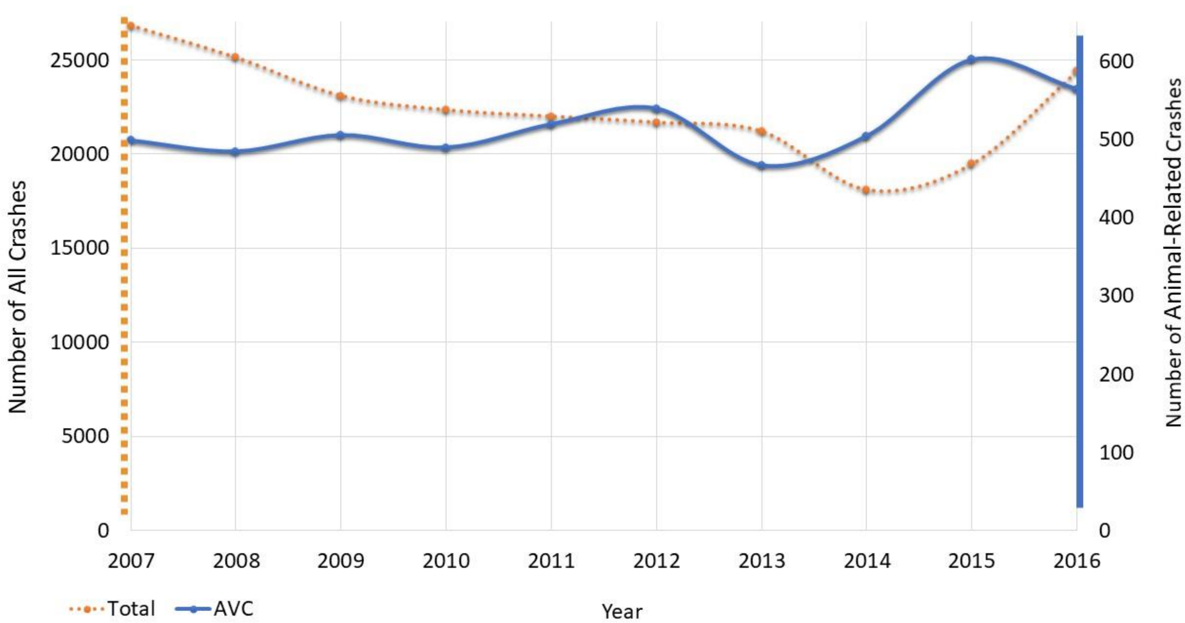


Figure 8. The Number of All Reported Crashes and Animal-Related Crashes for Nevada, 2007-2016. Orange Dotted Line = All Crashes (Y-Axis), Solid Blue Line = Animal Related Crashes (Z-Axis).

Estimated Costs to Society of Reported Animal-Related Crashes

Animal-related crash data from 2006 was added to the 10 years of 2007-2016 data to better inform the analyses of the severity of animal-related crashes. Of the total crashes where an animal was involved from 2006-2016, there were 14 human fatalities, or 0.25 percent of the total animal-related crashes. Overall, human fatalities (n=1,393) averaged 0.67 percent of all reported crashes. During the 2006-2016 period, animal-related reported crashes included 726 human injury related crashes, and 4,944 Property Damage Only (PDO) crashes. These were averaged to annual rates, and multiplied by crash values as used by NDOT Traffic Safety for 2016 crash values, to calculate an annual average cost of animal-related crashes in Nevada, see Table 10.

Table 10. Annual Cost of Crashes with Wild and Domestic Animals Based Solely on Nevada Department of Transportation Average Crash Costs, 2006 – 2016.

Type of Crashes	Total of Type in 11 years 2006-2016	Annual Average	Nevada DOT 2016 Comprehensive Societal Cost Per Occurrence	Total Average Annual Cost
Property Damage Only	4,944	450	$ 10,221	$ 4,599,450
Injury Crash Type C or Unknown Severity	383	34.8	$ 63,434	$ 2,207,503
Injury Crash Type B	278	25.3	$ 112,708	$ 2,851,512
Injury Crash Type A	65	5.9	$ 308,595	$ 1,820,711
Fatality	14	1.3	$ 5,839,241	$7,591,013
Total	5,683	516	Not applicable	$ 19,070,189

The average annual cost to society for reported animal-related crashes in Nevada was over 19 million dollars. This value does not include the value of the animals killed.

Estimated Number of Wildlife Killed in Collisions and Their Worth

Generalized estimates can be made as to the number of wild animals killed in crashes in Nevada, and their worth. An estimate of the large wild mammals killed in collisions can be estimated using conversion indices. In Utah, Olson (2013) found 5.26 mule deer carcasses along Utah highways for every one reported WVC crash, (species are not recorded in crash records, but the majority of carcasses are mule deer so they are predicted to be the number one species involved in crashes; Olson 2013, Olson et al. 2014a). In Virginia, the ratio was as high as 9.7 white-tailed deer carcasses collected for every reported WVC crash (Donaldson and Lafon 2008). The magnitude of unreported collisions with wildlife is largely due to factors involving lack of incentives for motorists to report the incidents to the authorities and their insurance agency. If 27 percent of the annual average of 516 reported crashes with animals is with domestic animals; horses, cows, and burros (see data tables below), then the annual average of reported crashes with wild animals is approximately 377. If this number is multiplied by Olson's Utah factor (5.26), then approximately 1,983 mule deer and other large wild mammals are killed along Nevada's roads administered by NDOT.

The value of wildlife is not listed as a factor in the above crash value calculations. The NDOW game wardens' estimated values of various wildlife species in criminal cases of poaching can be used as the base of rough estimates of the value of wildlife killed in vehicle crashes (see Chapter Four on Task 3 for table of values). These estimates value an individual large mammal from $250 to $30,000. The higher values are for trophy male ungulates with large antlers. If the average value of a large mammal killed on Nevada highways is estimated at a value of $1,000, (South Dakota Game Fish and Parks places this value for a single white-tailed or mule deer, see Cramer et al. 2016), then the estimated 1,983 average number of large mammals killed on Nevada roads would be worth $1,983,000.

It is estimated that an average of 1,983 large wild mammals are lost annually to collisions, based on the Utah 5.26 carcass to reported crash correction value. When the value of these lost animals is estimated at $1,000 per animal, based on an average of Nevada Department of Wildlife individual animal values, these animals are worth over 1.9 million dollars lost to the Nevada public each year.

The estimated value of reported animal-related crashes plus reported carcasses of wild animals cost the residents of Nevada over 21 million dollars annually.

Crashes by County, Rural Areas of Nevada, and by NDOT District

Animal-related crashes vary in numbers and as a proportion of total crashes across Nevada. The animal-related crash data from 2007-2016 were analyzed by county, for areas outside of Las Vegas and Reno, and by NDOT districts.

Crashes for the ten-year period were analyzed by county, and for the number of animal related crashes as a proportion of all crashes for each county, Table 11. The number of animal-related crashes was plotted by county, Figure 9. Elko County had the greatest number, followed by Lincoln County. The 2016 crash data included just 77 more animal related crashes than the 2006 data, an increase of 1.5 percent. The increase was negligible when related to total crashes, therefore the table of county-wide data for 2006-2015 was not updated for 2007-2016 due to the amount of time it would take and the minimal differences between the time periods. However, totals are for the 2007-2016 period are presented as a footnote to the table.

Table 11. Number of Total Crashes, Animal-Related Crashes, and Percentage of Total Crashes That Are Animal-Related, per County in Nevada, 2006-2015.

County	Total Crashes	Total Animal-Related Crashes	Animal Related %		County	Total Crashes	Total Animal-Related Crashes	Animal Related %
Carson City	2,572	78	3.0		Lincoln	1,451	674	46.5
Churchill	2,640	276	10.5		Lyon	2,934	310	10.6
Clark*	148,731	468	0.3		Mineral	701	105	15.0
Douglas	4,591	260	5.6		Nye	3,054	301	9.9
Elko	6,271	923	14.7		Pershing	848	92	10.8
Esmeralda	456	35	7.7		Storey	348	49	14.1
Eureka	1,126	175	15.5		Washoe$^{\Delta}$	31,223	549	1.8
Humboldt	1,972	327	16.6		White Pine	1,611	384	23.8
Lander	776	105	13.5		Totals	211,305**	5,111**	2.4**

* Las Vegas is in Clark County. Δ Reno is located in Washoe County.

** From 2007-2016 the number of total crashes was 252,236; animal-related crashes were 5,189; and animals were involved in 2.1 percent of crashes.

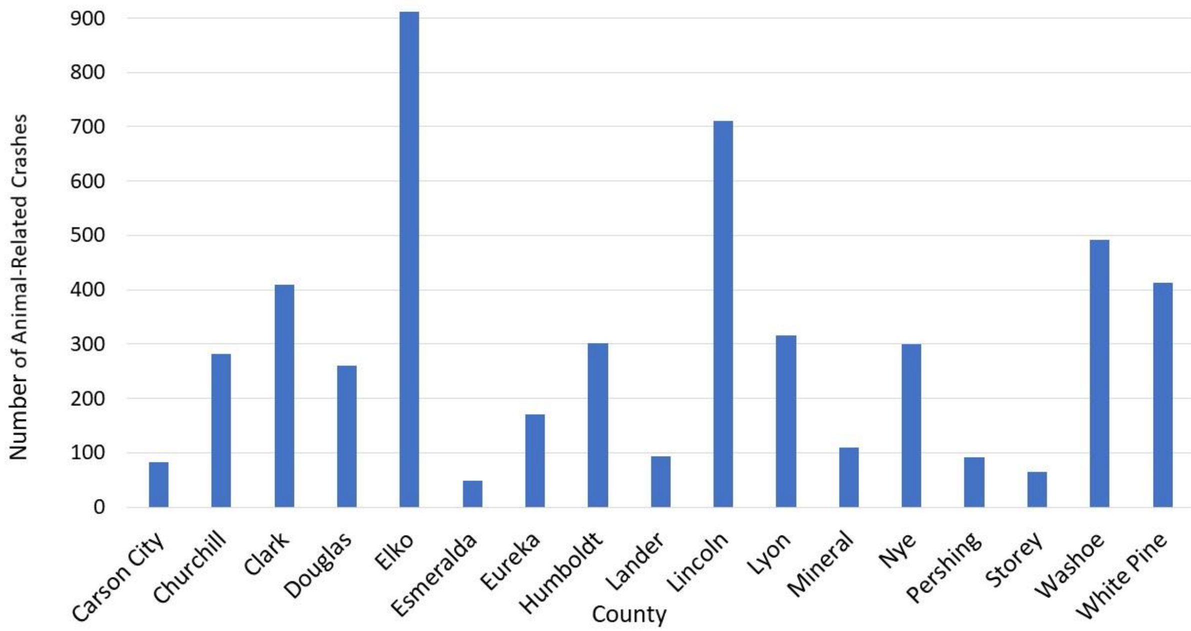


Figure 9. Number of Animal-Related Crashes from 2007-2016 for Nevada Counties.

If Clark County, home to Las Vegas, and Washoe County, where Reno is located, are taken out of the data, there were 31,351 total crashes in the remainder of Nevada. Within those counties, there were 4,094 animal-vehicle crashes, which were 13.1 percent of the crashes.

In the 15 rural counties of Nevada, animal-related crashes account for 13 percent of all crashes.

The research panel members were interested in exploring if the large number and percentage of crashes in the two largest cities in Nevada, Las Vegas and Reno were overwhelming the animal-vehicle crash data. To explore this, the municipal boundaries of Las Vegas and Reno were used to excise these cities from the crash database. Animal-related crashes went from 2.3 percent to 3.5 percent of all reported crashes.

Perhaps the data presented in Table 12 are most informative. The number of total reported crashes and animal-related crashes for each NDOT District are presented. NDOT District III had 16.2 percent of its crashes reported to involve an animal. This is the district with the least amount of horse and cattle crashes, and the greatest percentage of crashes that are with wildlife. NDOT District II, the Reno District, has the greatest number of all animal related crashes.

Table 12. Number of Crashes and Animal-Related Crashes per Nevada DOT District, 2006-2015.

Nevada Department of Transportation District	Total Number of Crashes from 2006-2015	Number of Animal-Related Crashes 2006-2015	Percentage of Crashes That Were Animal-Related
District I Las Vegas	153,692	1,478	0.96
District II Reno	47,821	2,083	4.28
District III Elko	9,776	1,591	16.22

Types of Animals Involved in Crashes and Collected as Carcasses

Crash data records and queries described above revealed the type of animal involved in the crash in the database columns 'first harm event' and 'most harm event.' Total crashes for 2006-2015 that involved each species are detailed in Table 13, below. The top five species most often involved in these crashes, were, in descending order: deer, cattle, horse, coyote/dog, and elk. Deer-involved crashes totaled more than all other animal-related crashes combined.

Table 13. Number of Reported Crashes and Carcasses Collected for Each Animal Type in Nevada 2006-2015, in Descending Order.

Species	Number of Crashes Reported to Involve the Species	Annual Crash Average	Number of Carcasses Recorded	Annual Carcass Average
Deer	2,665	266.5	2,984	298
Cattle	786	78.6	249	25
Horse	348	34.8	176	17.6
Coyote/Dog	289	28.9	9	0.9
Elk	231	23.1	160	16
Burro	166	16.6	124	12.4
Other/Unknown	99	9.9	99	10
Antelope (Pronghorn)	88	8.8	106	10.6
Bear	54	5.4	20	2
Bighorn Sheep	39	3.9	16	1.6
Rabbit	22	2.2	0	0
Bobcat	0	0	8	0.8
Hawk/Owl/Eagle	0	0	194	19.4
Puma (Mountain lion)	0	0	80	8
Sheep or Goat	0	0	5	0.5
Raccoon	0	0	1	0
Tortoise	0	0	2	0.2
Turkey	0	0	1	0

Table 14 presents the crash severity data for the different species of animals involved in the three types of crashes reported to NDOT.

Table 14. Number of Crashes of Different Severity Involving Wild and Domestic Species of Animals in Nevada, 2006-2016.

Type of Animal	Number Crashes Reported with Each Species 2006-2016				
	Fatal	Injury	Property Damage Only	Total	Comments
Deer	1	238	2,479	2,718	.03% of crashes were fatal, 9% caused injuries
Cow (Cattle)	2	141	661	804	0.2% of crashes were fatal, 18% caused injuries
Horse	5	76	276	357	1.4% of crashes were fatal, 21% caused injuries
Dog/Coyote	3	77	304	384	0.7% of crashes were fatal, 20% caused injuries
Elk	1	34	185	220	0.5% of crashes were fatal, 15% caused injuries
Burro	0	31	140	171	0% of crashes were fatal, 18% caused injuries
Pronghorn Antelope	1	10	81	92	
Bear	0	9	46	55	
Bighorn Sheep	0	6	33	39	Majority of crashes were in Clark County on US 95, & US 93
Bird	0	1	11	12	
Sheep	0	3	5	8	Domestic sheep, solo and in herds
Ducks	0	1	1	2	
Fox	0	2	1	3	
Rabbit	0	7	15	22	Dozens of attempts to avoid hitting rabbits
Unknown	1	91	704	796	
Total	14	727	4,945	5,683	

The animals that caused the most human fatalities in crashes (2006-2016), were, in ranked order: horses, dog/coyote, cow, and then the ungulates - deer, elk, and pronghorn antelope, see Table 15 below. The locations of these fatal crashes were mapped, Figure 10.

Table 15. Locations of Fatal Crashes with Different Animal Species, 2006-2016.

Type of Animal	Number Reported	Roads & Mile Markers							
		US 50	**USA PKWY**	**IR 80 E**	**US 6**	**US 93N**	**SR 379**	**SR 445**	**SR 487**
Deer	1			EL 113					
Cow	2	90**					NY 3		
Horse	5	LY 25, LY 11			MI 14	EL 49		WA 10.7	
Dog/Coyote	3	6**		EU 2, LA 18					
Elk	1				WP 85				
Pronghorn Antelope	1								WP 4
Unknown	1		ST 0 near FRWA16						
Total	14								

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LA=Lander, LN=Lincoln, LY=Lyon, NY=Nye, MI=Mineral, ST=Storey, WA=Washoe, and WP= White Pine.*
** Note – these two crashes occurred in 2006 and do not appear on the map of fatal crashes from 2007-2016.

Of the 12 fatal crashes with animals from 2007 through 2016, motorcycles were involved in four of those crashes.

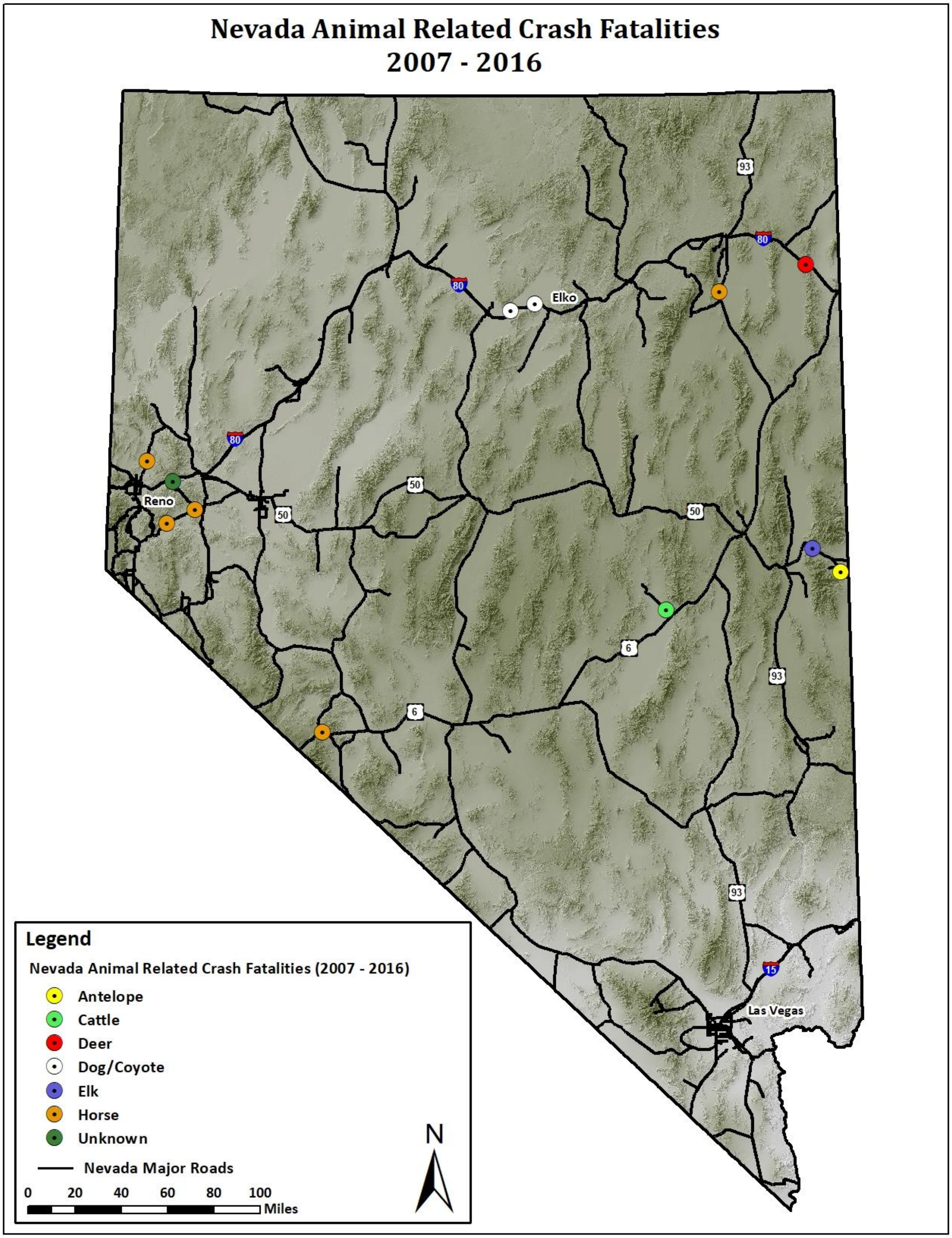


Figure 10. Fatal Crashes Reported Due to Animals, Nevada 2007-2016.

The horse is the most dangerous animal for the traveling public: five humans have died in crashes involving horses (from 2006-2016), and 21 percent of crashes with horses resulted in reported human injuries, the highest rate for any species. Dogs and coyotes were more dangerous than deer for motorists involved in accidents: there were three human deaths in these crashes, and 20 percent of the 387 dog/coyote crashes created human injuries. Surprisingly, although there were 2,718 reported crashes with deer over 11 years of data, only one motorist died in a deer-vehicle crash, and the crashes with injuries were just nine percent of all these crashes.

Literature Review

The literature review is presented in Appendix B. There are two parts: a table of western U.S. states' efforts to map wildlife-vehicle collisions and carcasses and status of standardized wildlife mitigation planning, and articles, books, websites; and reports pertinent to this study.

The literature review and communication with western state colleagues revealed several common practices in the reduction of wildlife-vehicle conflict. To best identify wildlife-vehicle conflicts and then prioritize appropriate actions, states typically undertake four steps: collect crash and carcass data, map WVC carcass and crash data, identify potential wildlife linkages, and create a standardized prioritization methodology for identifying and creating wildlife mitigation. Most states have not completed every step. Idaho is the exception.

The noteworthy leaders for each of these steps included the following. Idaho, Utah, and California are leaders for carcass data collection on devices (Utah), or via websites (California and Idaho) that immediately upload the data to interactive maps. There are two types of mapping, those that are interactive, as mentioned is done by the three above states, and can be called mapping 'on the fly', and those processes that are more in-depth and create static maps, with both carcass and crash data. Static maps have been created as part of projects for Idaho (Cramer et al. 2014), Colorado (Crooks et al. 2008), South Dakota (Cramer et al. 2016), Nevada (Gibby and Clewell 2006), Arizona (Dodd 2014), Washington (Meyers et al. 2008), and Oregon (Trask 2009), among others.

Wildlife linkages have been identified with hypothetical GIS models, GIS models based on wildlife locational data, and through expert opinion sessions. A ground breaking wildlife linkage mapping that used quantifiable models was the Arizona Wildlife Linkages project (Nordhaugen et al. 2006). Beier's methods were used in this Arizona Linkages and in California (Beier et al. 2006) and adapted for Washington (Washington Wildlife Habitat Connectivity Working group 2010). These analyses use least-cost path modeling analyses, with some input of empirical data on wildlife locations. The Western Governors' Association lead a multi-state connectivity modeling plan (Western Governors 2013). Montana has adapted and taken the CHAT modeling tool to the farthest levels of analyses of any western state (Montana Department of Fish Wildlife and Parks 2018). Idaho created wildlife linkage maps based on expert opinion taken through regional workshops (Inghram et al. 2009), which was typical of earlier efforts prior to landscape scape map modeling. Taken together, these steps provided data to help states become proactive in creating a strategy on how to deal with wildlife-vehicle conflict. Idaho was the first state to create a systematic prioritization process and report on the top areas to deal with wildlife-vehicle conflict (Cramer et al. 2014). The effort resulted in several actions, including a Memorandum of Understanding between Idaho Transportation Department and Idaho Game and Fish, See Appendix C. Washington State and Arizona Departments of Transportation (DOT's) had in house efforts to create such processes, but they were not standardized and published (See Dodd 2014). At the time of this writing, the Colorado DOT and Colorado Parks and Wildlife Department were sponsoring a study (The West Slope Study) that will result in a prioritization process. This appears to be a common trend in states that are starting to standardize how information is brought together to determine the need for wildlife mitigation. At the time of this writing Texas DOT was working on such standardization with the University of Texas at Austin, with Dr. Cramer as a partner. Montana sponsored a similar study that was not yet completed at the publication of this report.

Discussion

These analyses of wildlife and livestock crash and carcass data allowed an evaluation of costs of animal-related collisions, identification of the species most important to wildlife-vehicle conflict, county and NDOT District statistics, and an estimation of the data's shortfalls. Nevada's wildlife-vehicle conflict problems were found to include livestock as well. Deer were the number one animal involved in animal-vehicle crashes with as many deer-related crashes as all other animal crashes combined. The analyses demonstrated that livestock play a major role in animal-vehicle crashes: cattle and horses are second and third and burros are fifth for sheer numbers of vehicle crashes with different species. In fact, horses are the most dangerous animal to motorists; accidents with this species kill and injure a greater proportion of motorists involved in horse-vehicle crashes than any other species' crashes. The tally of species' crash numbers was possible because Nevada's data reporting system allows traffic safety officers to record species involved in crashes. This system is a step ahead of other states, and allows for robust analyses. This allows for a better prescription of mitigation options.

The evaluation of the processes of how crash and carcass data are collected revealed strengths and weakness in both processes. The greatest strength of the crash data is the inclusion of species' names in crash forms, and is a very proactive step in helping to address problems with wildlife and livestock on the road. The recent (2016) changes to the PDO reporting short forms have added animal species' pull-down menu list. The greatest weakness of the carcass data is the lack of consistent reporting. There needs to be a greater commitment to carcass data reporting by NDOT maintenance personnel. Records for the carcasses are near equivalent or less than the total crashes recorded with those species. Maintenance workers in most states record far more carcasses than crash stats reveal. As mentioned earlier, Donaldson and Lafon (2008) found maintenance personnel recorded greater than nine times more white-tailed deer carcasses than reported in police crash records. A problem cannot be addressed if it is not identified. Carcass collection data are crucial to addressing wildlife-vehicle conflict at a local level.

Wildlife and livestock are a greater portion of total crashes in the 15 rural counties (13 percent), than the overall state average of 2.3 percent. The state-wide statistics do not reflect this due to how the data are overwhelmed by the number of crashes in the urban areas of Las Vegas (Clark County) and Reno (Washoe County), which account for over 70 percent of all crashes recorded. When these cities' crash data were removed from the overall crash data set, animal-vehicle collision crashes accounted for 3.5 percent of all crashes, which was lower than expected.

These more in-depth analyses demonstrate the need to refine data searches according to different factors. In this analysis, it is evident that animal-related crashes are a larger portion of overall crashes in the majority of the geographic regions of the state. In two counties, these animal-related crashes are over 20 percent: White Pine County = 23.8 percent, and Lincoln County = 46.5 percent.

Finally, placing a value on the recorded crashes with animals helped Nevada observe the cost to society of those crashes annually. With an over $19 million average annual cost in reported crashes alone, the problem of vehicles and wildlife and livestock creates a challenge to improve driver safety on Nevada's roads. If PDO short crash reporting forms could allow better reporting of the animal involved in the crash, these numbers would increase and would better reflect the extent of these collisions. Once NDOT maintenance across the state improves carcass data reporting, the state would also get a clearer picture as to the extent of the wildlife loss.

The literature review and communication with western state DOT colleagues revealed the four common steps to reduce wildlife-vehicle conflict: collect crash and carcass data, map WVC carcass and crash data, identify potential wildlife linkages, and create a standardized prioritization methodology to identify and create wildlife mitigation. Most states have not completed every step. Idaho is the exception. There are smart phone apps and computer software in several states that allow users to upload carcass data collection (Idaho, California, and Utah). In turn, the websites associated with these data allow on the fly mapping, which is very helpful in efforts to look at specific places in time and through various filters for types of wildlife, and mile posts for segments of road. This is the future of carcass and crash mapping.

Wildlife linkage mapping can be important and has been accomplished to various degree in states. A cautionary word about this approach, the linkages are very subjective to the creators' hypotheses and may not actually exist when mapped with empirical animal radio and GPS collar data. Therefore, a state without wildlife linkage maps may have better flexibility in the future to create maps that are based on data that will be a true representation of how species of interest move on the landscape. Alternatively, there is cause for concern that mapping wildlife linkages and corridors leads to greater development of their federal land habitat. Extractive industries and their federal regulators may view the remaining habitat as not crucial and subject to mining, road, and energy transmission. This will affect NDOT actions as well.

The prioritization processes to identify top areas for wildlife-vehicle conflict have become more common in western states, and have even gained regional support. Overall, U.S. states in the west are working through multiple methods to help reduce wildlife-vehicle conflict. Nevada has become a leader in the area of rapidly creating wildlife crossing overpass structures. With the development of this project, Nevada is poised to complete the other steps in the practice of mitigating roads for wildlife.

Recommendations

Several improvements can be made to the existing processes of collecting data and troubleshooting areas where animals are known to be involved in crashes.

- Nevada DOT - Traffic Safety - Law enforcement crash locational data should be automatic GPS locations that are instantly geo-referenced. This would eliminate the time and errors of NDOT personnel transposing the estimates written by officers of where they believe the location was, or where they pulled their vehicles over to input data into electronic forms.

- Nevada DOT - Maintenance workers will need to be able to use an electronic method to upload carcass data GPS locations, species of animal, age, and gender. As of 2018 there were efforts to create such methods with IPads and IPhones.

-Nevada DOT - Maintenance workers, supervisors, and overall institutional hierarchy need to be convinced that collecting data on carcasses is an important part of their job and the operations of NDOT to help find solutions to decrease crashes with animals.

- Nevada DOT Maintenance personnel can be educated on the importance of carcass data collection during their education at the Maintenance Academy.

- Nevada DOT overall will need to assess areas where horses, cattle, and burros are involved in collisions and look for improved fencing and cattle guard placement to help reduce these collisions.

- Nevada DOT – overall will need to take additional information from this report to address the problems of wildlife access to roads with the highest incidences of wildlife-vehicle conflict.

- Nevada DOT Traffic Safety can both promote and upgrade the NDOT Traffic Safety App (Nevada Department of Transportation 2018a) to analyze traffic crash data along roads rather than 20 mile hexagonal bins. This could help on the fly crash searches that involve wild and domestic animals.

CHAPTER 3 PRIORITY AREAS OF ANIMAL-VEHICLE CONFLICT WITHIN NEVADA

Introduction

The objective of Task 2 was to bring together resources that reside across multiple agencies to one location where both NDOT and NDOW personnel can easily access them to understand the potential and extent of wildlife-vehicle conflict across the state and within NDOT districts. This chapter details four sub-tasks performed: 1. Maps of individual species' crash and carcass locations; 2. Hotspot maps based on crash data with all animals, then just wildlife, only horses, and only cattle; 3. A map of wildlife-vehicle collision crashes placed over mule deer and elk habitat maps; and 4. hotspot maps of areas of animal-vehicle conflict concern based on safety and ecological data. These maps are available to NDOT personnel through the NDOT GIS Production Geodatabase, or in general at the NDOT network through NDOT GIS Services within the IT Division.

Methods, Results, Discussion, and Recommendations from Data Analyses and Mapping

Methods Used to Create Species' Crashes and Carcass Locations

Data and maps were brought together to inform this task. The information was gathered from NDOT, NDOW, and other resources

Nevada Department of Transportation Data

NDOT personnel Jason Gonzalez (when he worked for NDOT), Nick Bacon, and Chris Wright worked with the research team to provide necessary crash, carcass, and overall NDOT data. Nick Bacon continued as the team's point person for GIS related questions for NDOT. Chris Wright provided valuable GIS layers' information.

Nevada Department of Wildlife

The research team worked with NDOW personnel to obtain wildlife-related GIS layers available on the internet at the NDOW website. Chet VanDellen was the original NDOW GIS coordinator for the team and assisted with early 2017 data downloads. Empirical data on wildlife telemetry locations within a one-mile buffer of all NDOT roads were delivered to the team by NDOW Big Game Staff Biologist Cody McKee in December of 2017. Additionally, NDOW Big Game Staff Biologist Cody Schroeder and Game Division Administrator Brian Wakeling, assisted with data, and the overall delivery of the project.

Other Data Sources

The team also obtained pertinent data layers from the U.S. Geologic Survey (USGS) National Map website, and the U.S. Census Bureau. The table of sources of geographic data consulted for the project is available in Appendix D.

Maps of crash and carcass locations were generated for the top nine species of wild and domestic animals. The research team used the crash and carcass data provided by NDOT to map the locations of crashes and carcasses of the top nine species of animals involved in vehicle accidents in Nevada, 2006-2015. These data were obtained through several queries NDOT personnel conducted, see Appendix A for methods.

Results

Maps are presented in Figures 11 through 19, below.

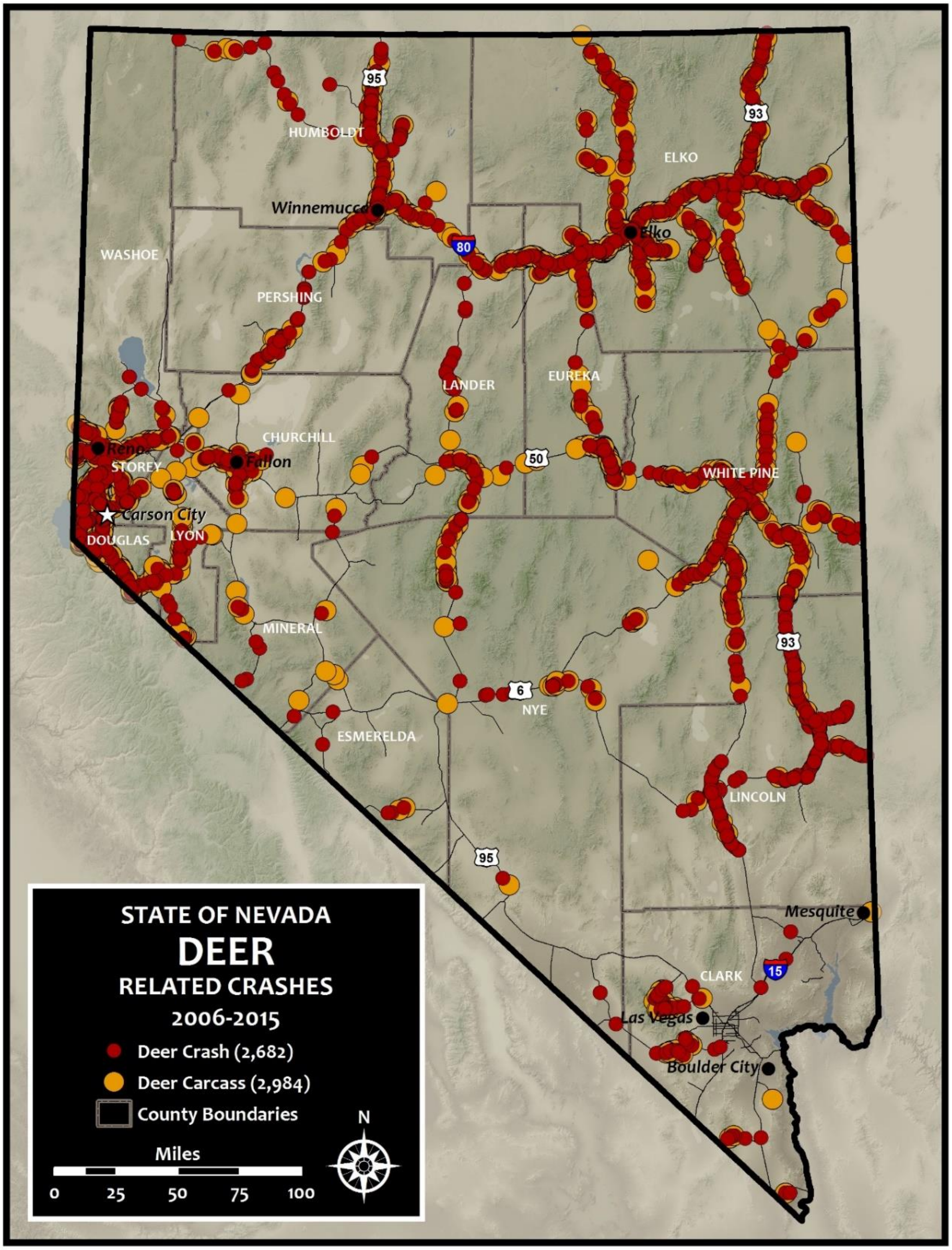


Figure 11. Mule Deer Crashes and Carcasses Reported in Nevada from 2006-2015.

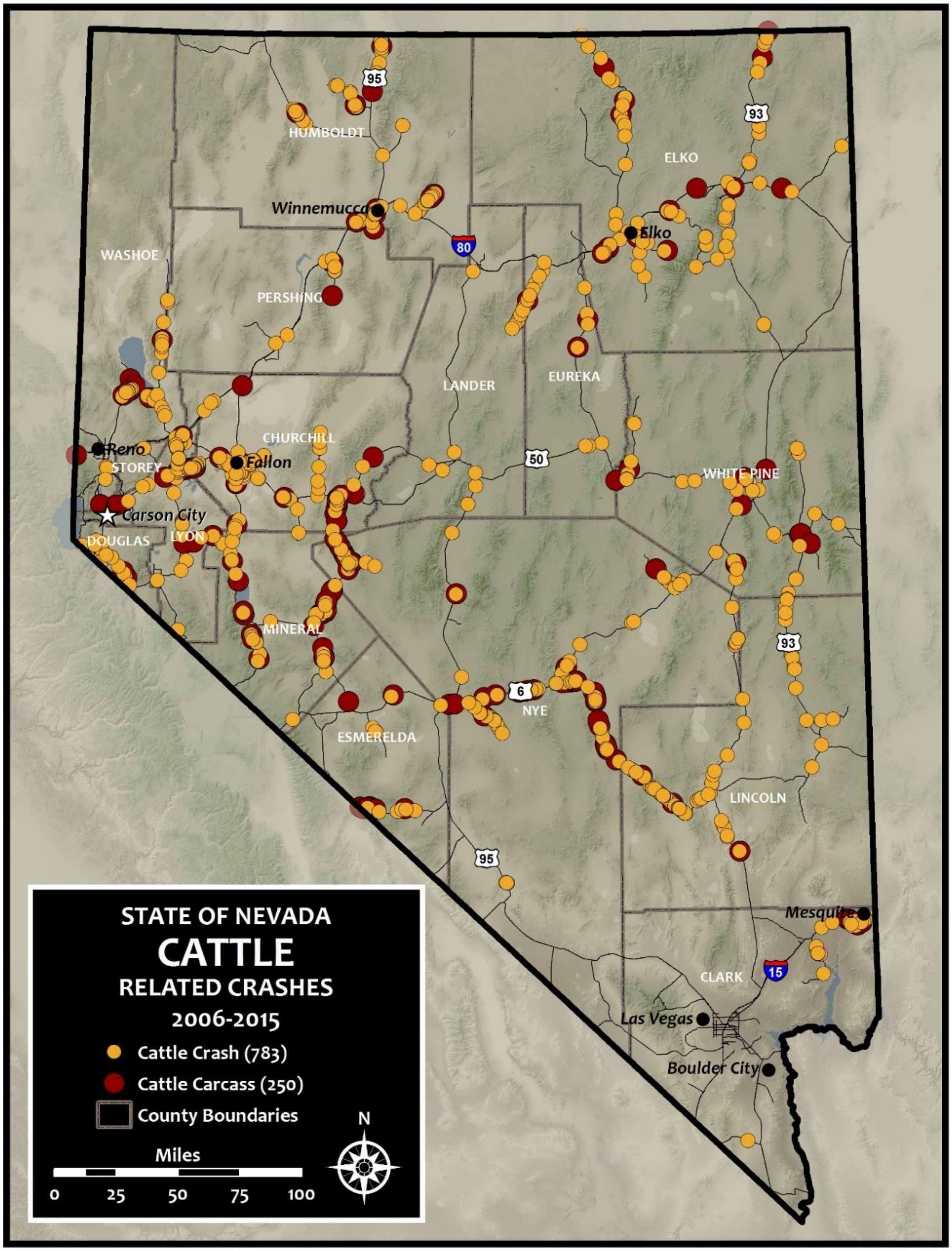


Figure 12. Cattle Crashes and Carcasses Reported in Nevada from 2006-2015.

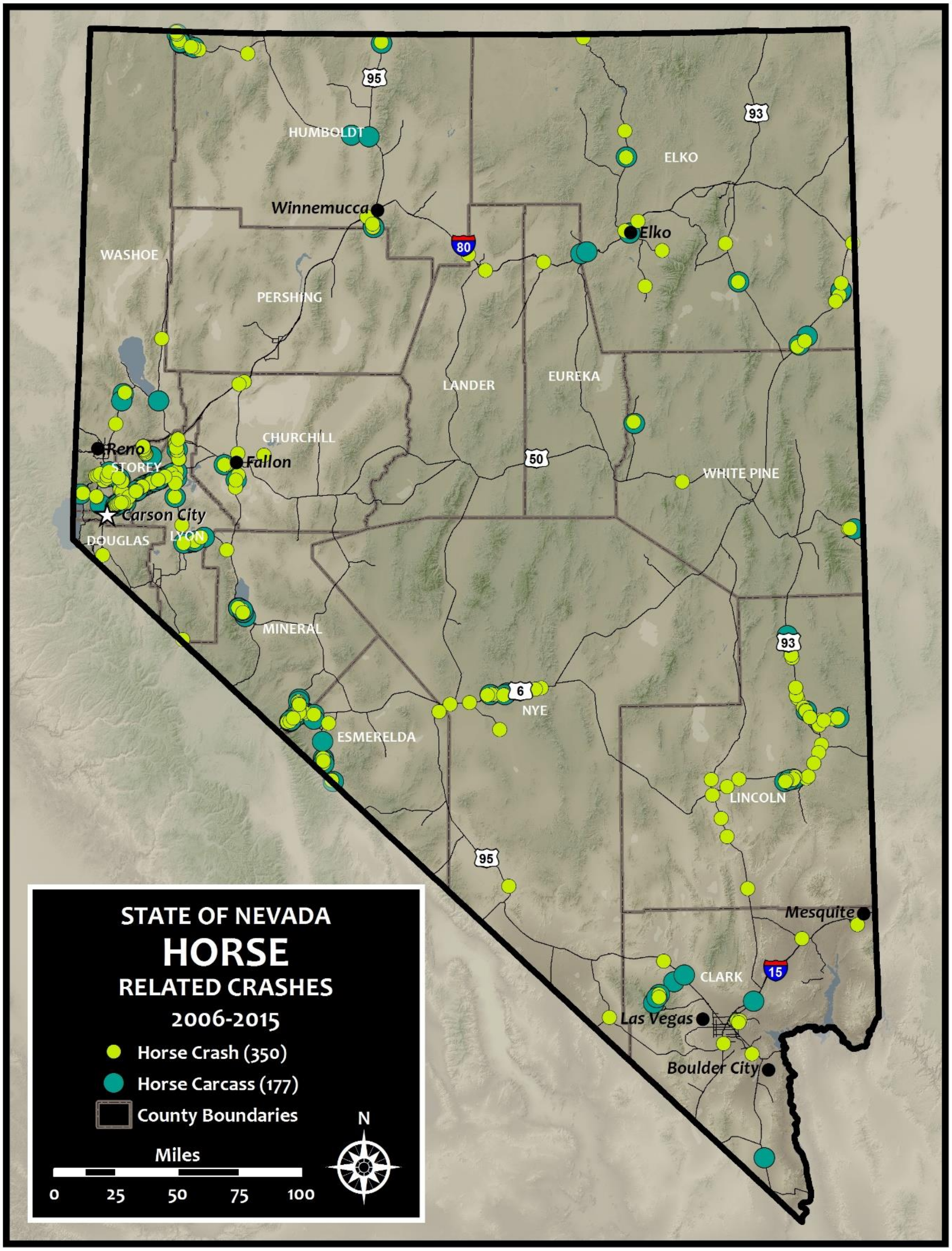


Figure 13. Horse Crashes and Carcasses Reported in Nevada from 2006-2015.

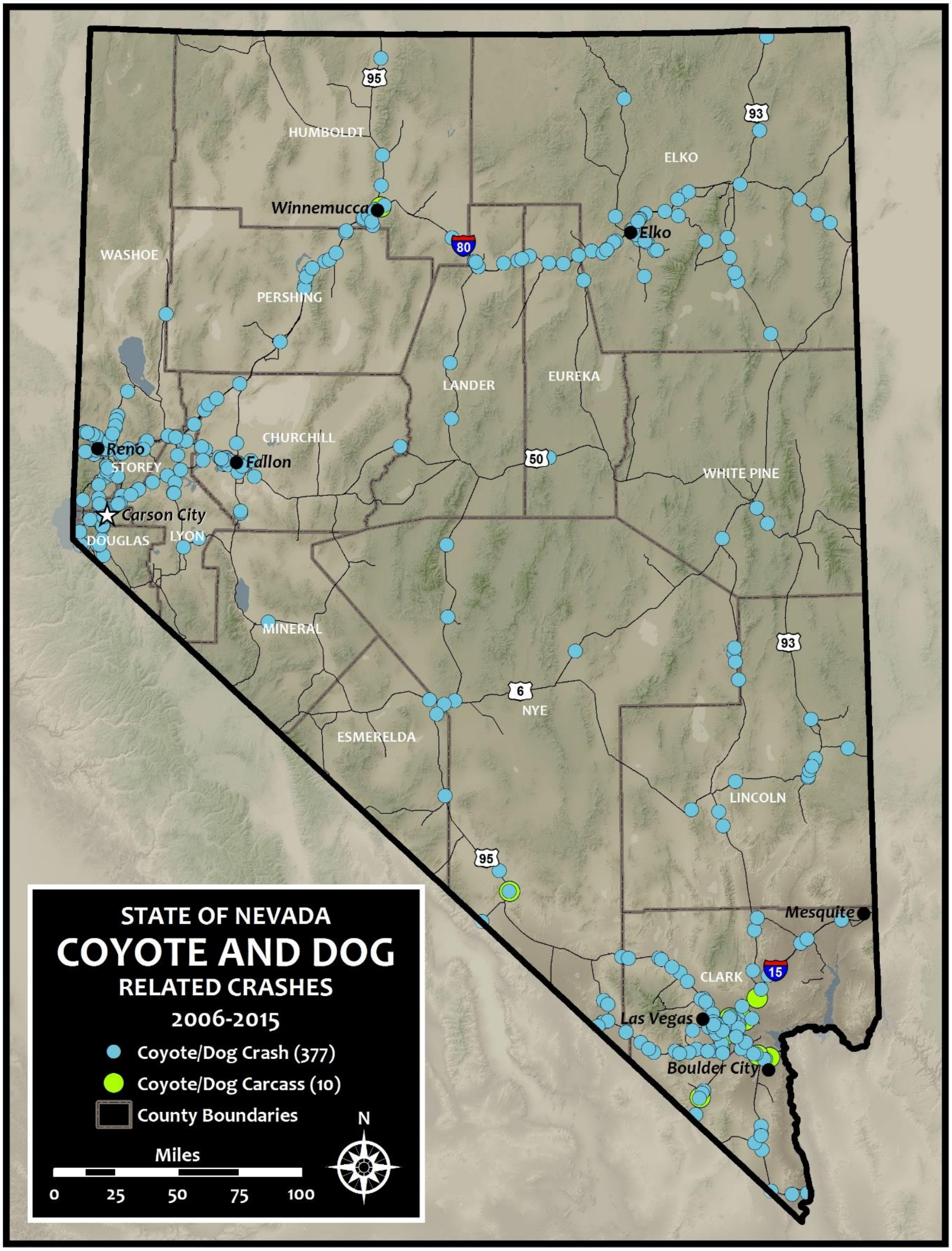


Figure 14. Coyote or Dog Crashes and Carcasses Reported in Nevada from 2006-2015.

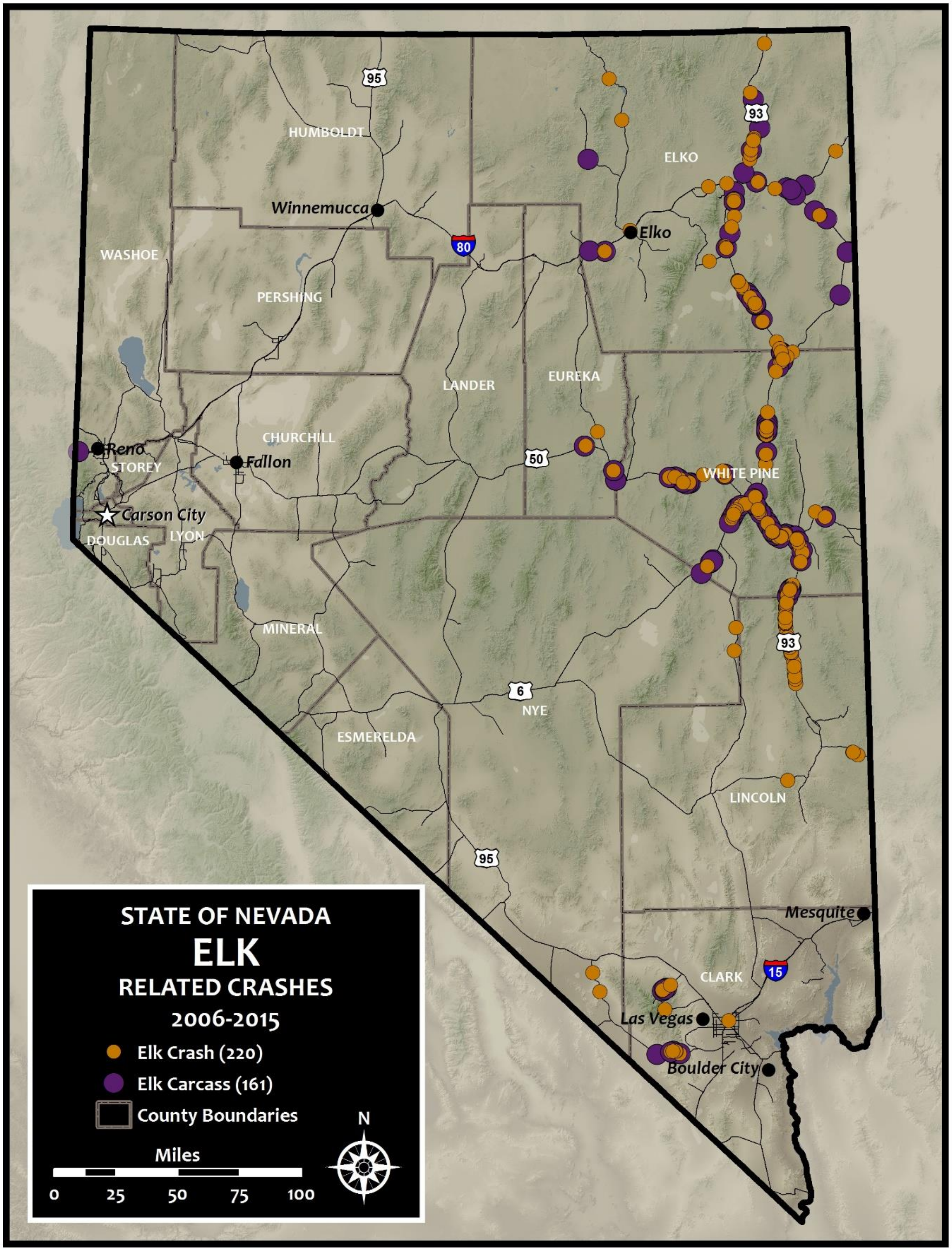


Figure 15. Elk Crashes and Carcasses Reported in Nevada from 2006-2015.

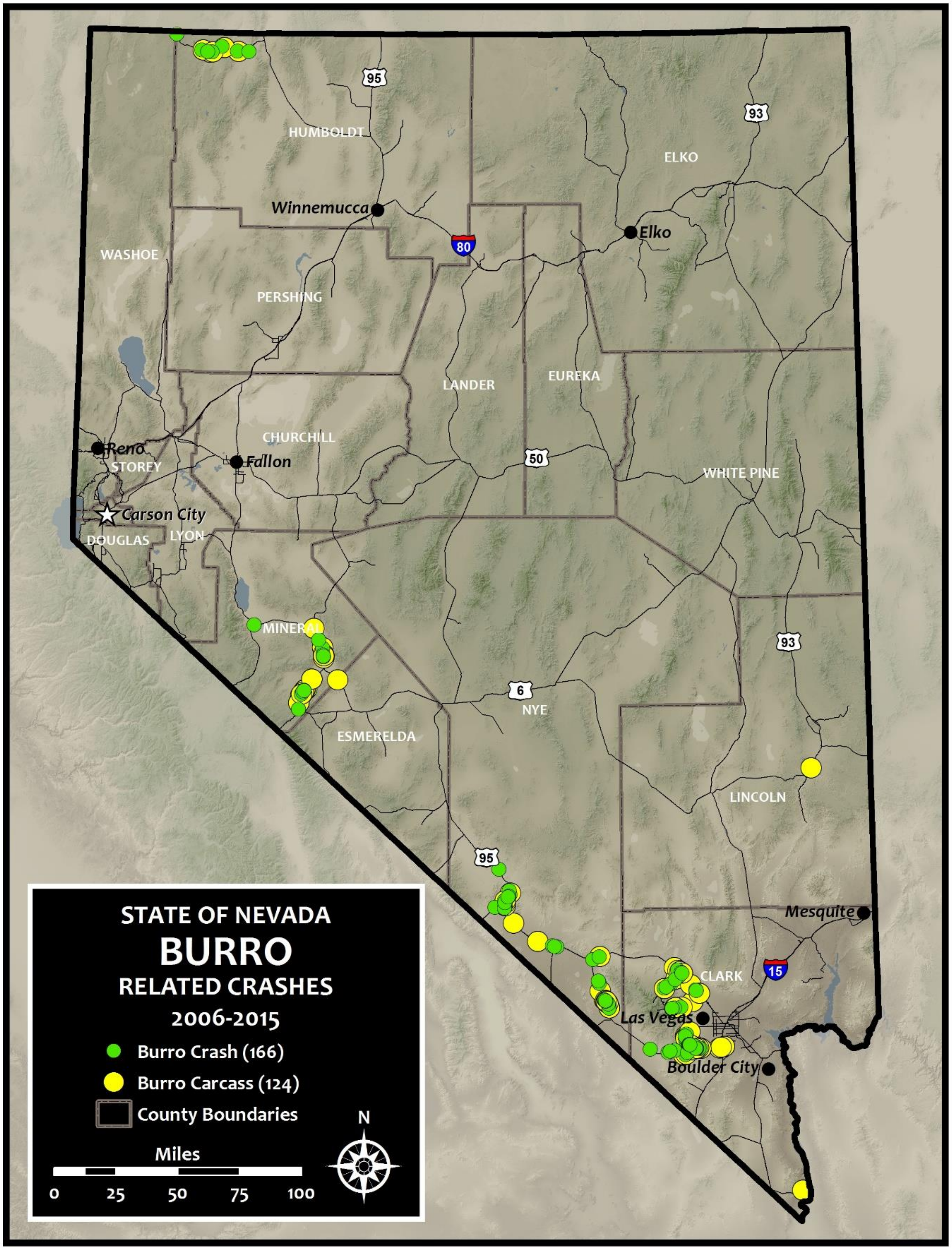


Figure 16. Burro Crashes and Carcasses Reported in Nevada from 2006-2015.

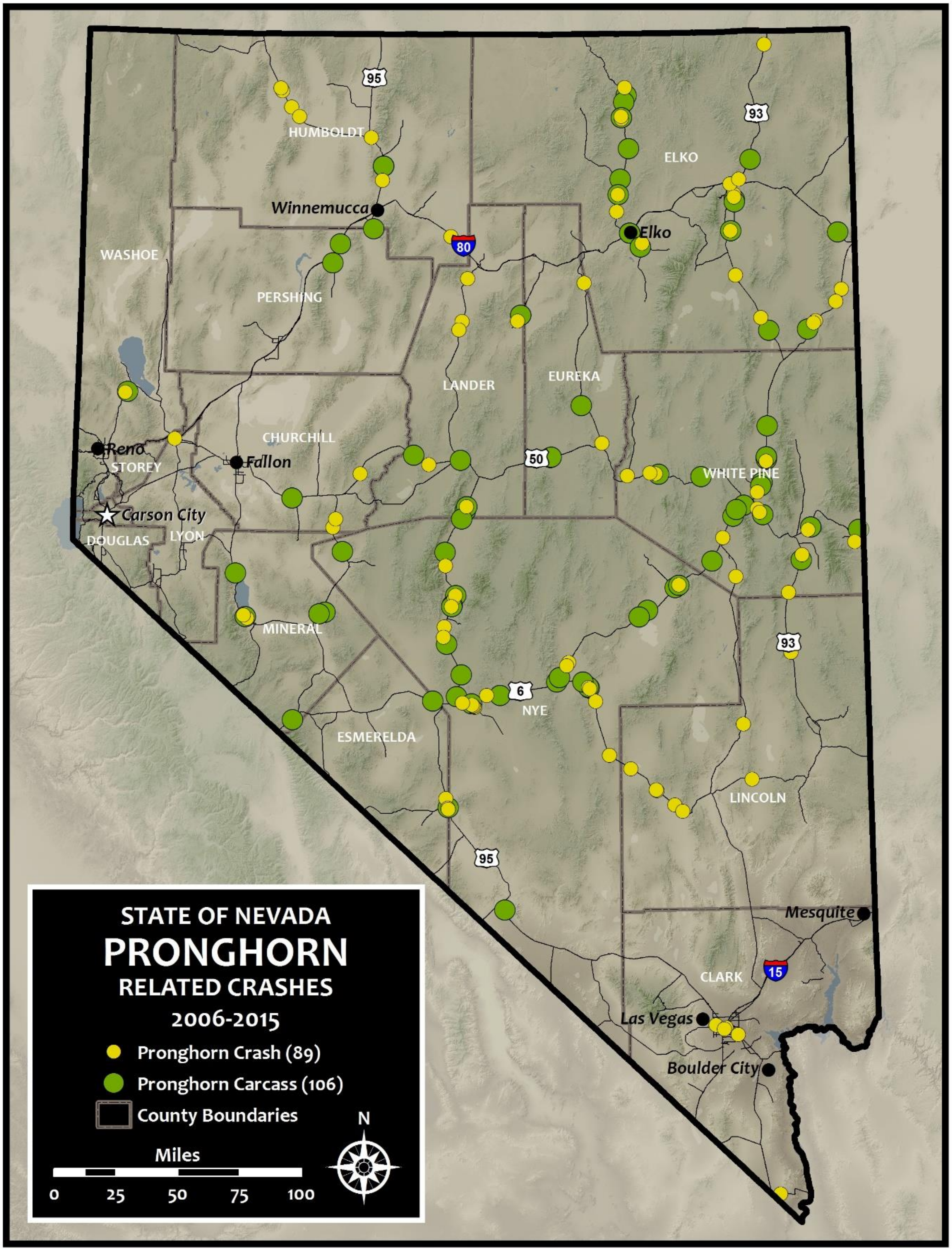


Figure 17. Pronghorn Antelope Crashes and Carcasses Reported in Nevada from 2006-2015.

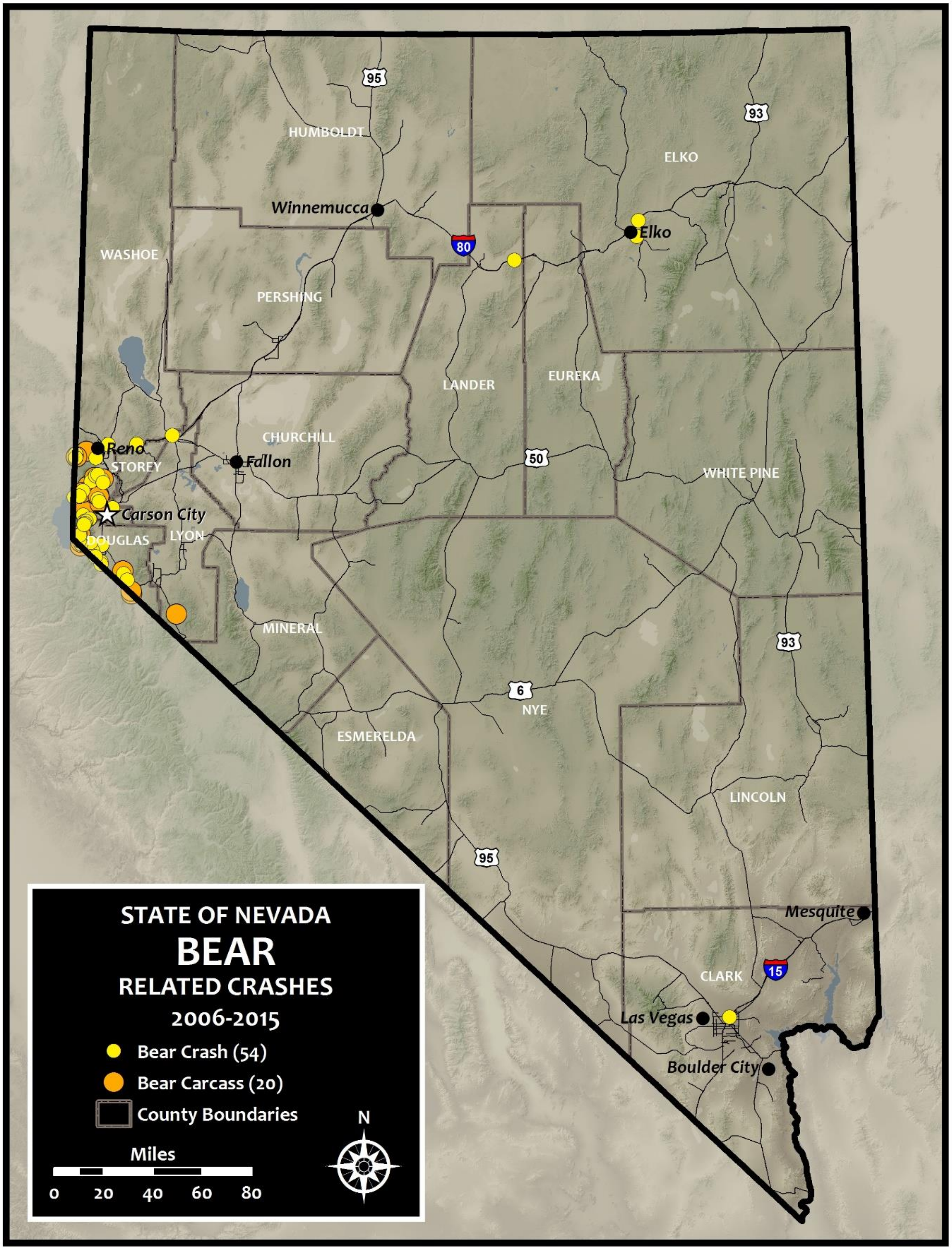


Figure 18. Black Bear Crashes and Carcasses Reported in Nevada From 2006-2015.

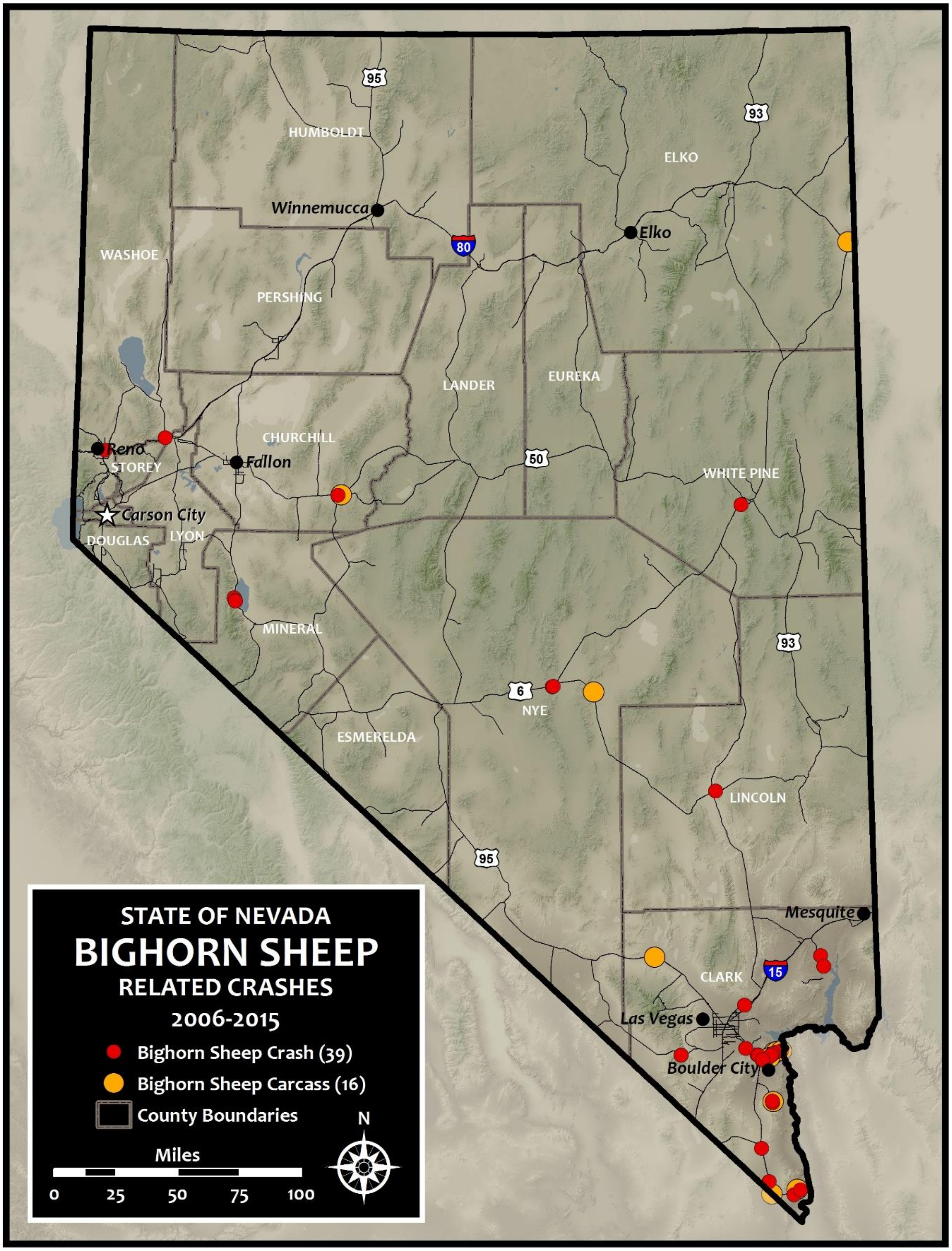


Figure 19. Bighorn Sheep Crashes and Carcasses Reported in Nevada from 2006-2015.

The research team worked with NDOT personnel to extract all fatal crashes reported to involve a rollover or run off the road accident. The 572 fatal incidents from 2007-2016 were mapped with mule deer and elk habitat maps laid underneath these crash data points (Figure 20), and the top 25 statewide animal-vehicle collision crash hotspots (created in the third sub-task of this chapter) laid over the crash points (Figure 21). These maps help to understand how these crashes may have been the result of the deceased driver's involvement in or avoidance of a crash with an animal that was not detected by law enforcement at the scene.

Discussion of Maps of Crashes and Carcasses in Nevada

Mapping of the animal-vehicle collision crash and carcass data allowed for targeted evaluations of what animal types were a problem in all areas of the state. These maps and maps from the analyses below will assist NDOT and NDOW in prescriptive solutions to reduce animal-vehicle collisions and potential conflict.

Of note is the information provided by the research panel members for this project on October 18, 2017. Through discussions it was learned that the southwestern area of the state has far more bighorn sheep and burro collisions than are represented in the database. Specifically, there were several to a dozen more bighorn sheep-vehicle collisions on the east side of Walker Lake on US 95, and burro-vehicle collisions that were not in the database that are known to regularly occur on US 95 South of Walker Lake and west of SR 361, and along SR 266. These are noted because county leaders in those areas have expressed concerns to NDOT Government Relations Coordinator, Lee Bonner. It is not known exactly why these collisions and carcasses are lacking in the databases. This concern brings up a valid point, that not all collisions with animals and not all carcasses are reported. THEREFORE, ACTIONS FOR PRIORITIZING MITIGATION MEASURES FOR ANIMALS ACROSS THE STATE SHOULD NOT BE BASED SOLELY ON CRASH AND CARCASS DATA.

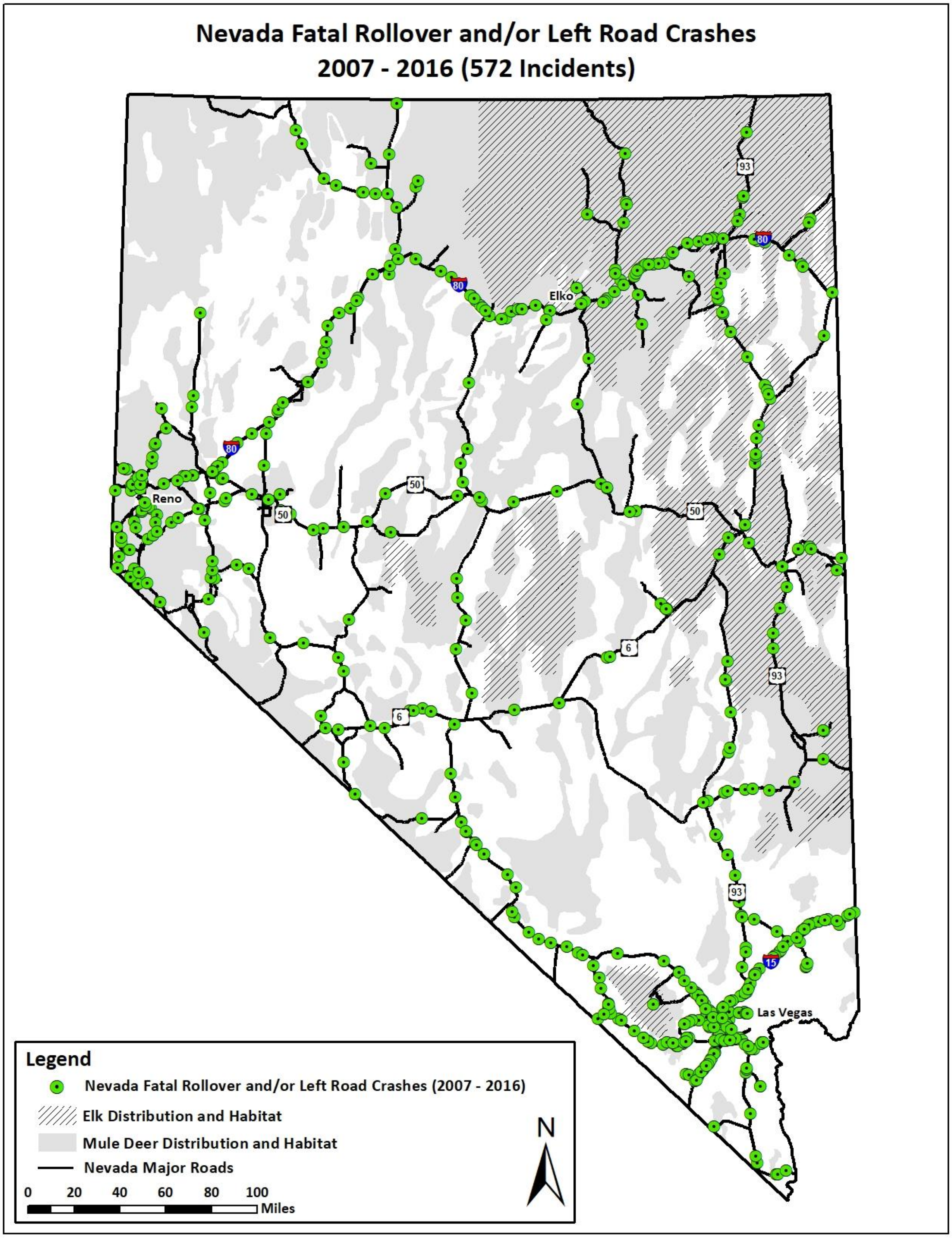


Figure 20. All Fatal Rollover or Left Road Reported Crashes in Nevada, 2007-2016 Plotted Over Mule Deer and Elk Habitat In Nevada.

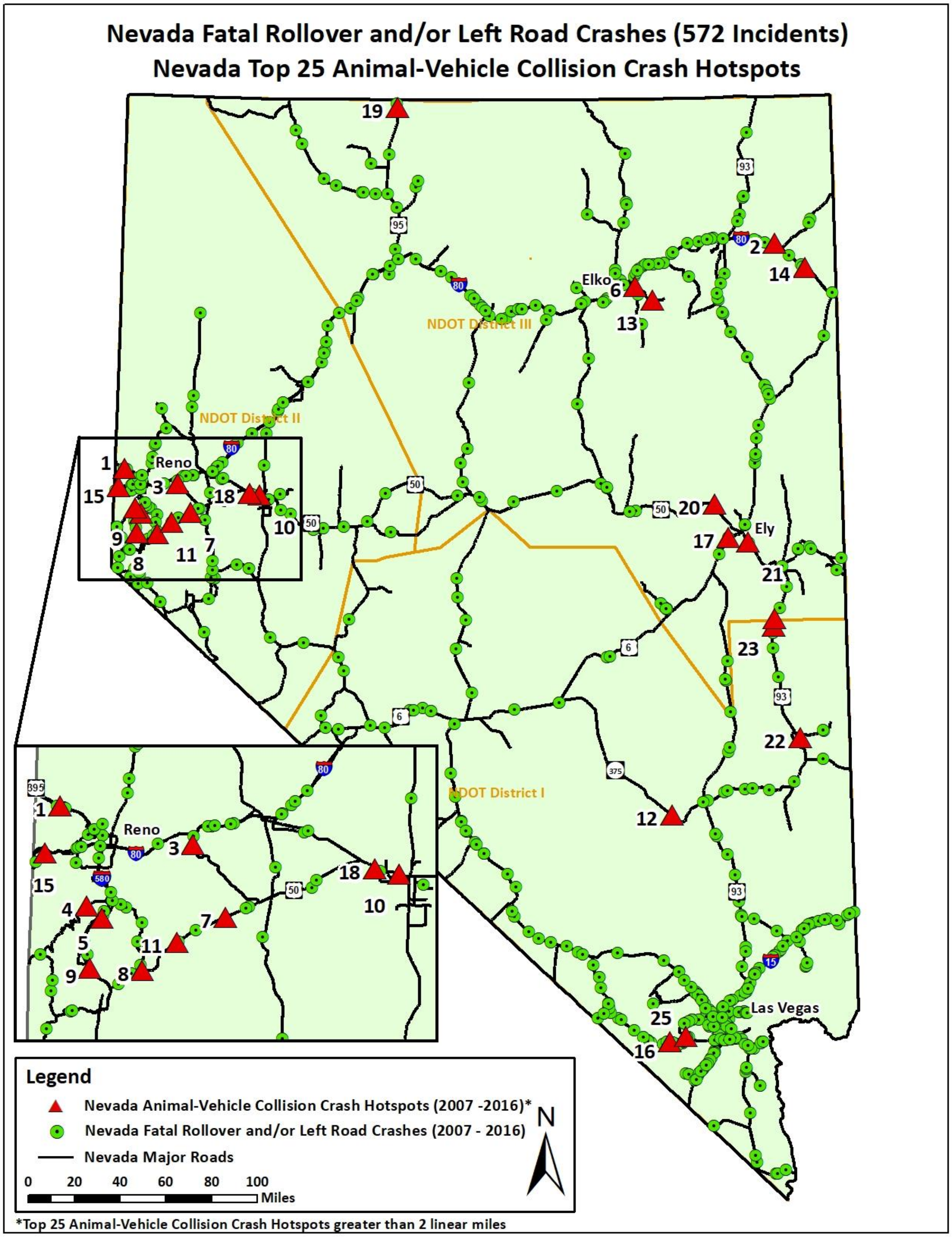


Figure 21. All Fatal Rollover or Left Road Reported Crashes in Nevada, 2007-2016 With Nevada State Top 25 Animal-Vehicle Crash Hotspots.

Methods, Results, and Discussion of Hotspot Mapping of Animal-Vehicle Collision Crash Data

Hotspot Analyses Methods

The second phase of these analyses was to create hotspot maps to identify priority areas for mitigation of wildlife-vehicle collision crashes. The research team learned from the panel that horse and cattle collisions were a concern, so the main analyses were kept at the animal-vehicle collision crash level, and then parsed out for wildlife, horse, and cattle crash data. The team plotted the data using three GIS analyses in ArcGIS: Point Density, Kernel Density Analysis, and the Getis-Ord Spatial Statistic Analysis. After months of plotting and analyzing the crash and carcass data using the three different methods and varying road segment size and search distance, the Getis-Ord Spatial Statistic was chosen as the most suitable, with the most accurate results, that could be defended statistically. The crash data were selected as the only database to use in these analyses because they were the most consistently collected data.

Getis-Ord has become, across the globe the to-date accepted best method to analyze animal-vehicle collisions to create statistically sound hot spots (Garrah et al. 2015, Kociolek et al. 2016, Shilling and Waetjen 2015). The hotspots that result from Getis-Ord are based on an aggregation of occurrence data. In this modeling the occurrence data were crash locations for various types of animals. The Getis-Ord modeling was run through testing several different lengths of the segments of all NDOT administered roads and search distances to find the best match for the data and size of the state. The optimum selections for these factors became a half-mile segment, a one-mile search distance, and the use of both the 95 and 99 percent confidence intervals. The Getis-Ord modeling was run multiple times through these different iterations, and the top 25 hotspots were generated for all animal-vehicle collision crashes, horse-vehicle collision crashes, cattle-vehicle collision crashes, and wildlife-vehicle collision crashes. The animal-vehicle collision crashes became the master map for the study.

When further analyses found some of the resulting top 25 hotspots for animal-vehicle collision crashes were less than two miles in length, the researchers parsed these shorter segments out of the top 25 priority hotpots and placed them with other smaller segment hotspots from the master map, to create a top 25 small hotspot list. This is because in the transportation world, a length of road less than two miles can receive animal-vehicle collision mitigation differently under different budgets and plans than a longer hotspot that can be as much as 15 miles in length. Specific descriptions of the methods used are explained in Appendix E.

The carcass data collection was inconsistent across the state, which make the strength of these data weaker and less predictable to draw statistically scientific conclusions from, therefore the carcass data were not included in the Getis-Ord prioritization process.

Hotspot Analyses Results

Top 25 Priority Hot Spots for Animal-Vehicle Collision Crashes Segments Two Miles and Greater in Length

The top 25 hotspots for crashes with all animal types are presented in Figure 22. Table 16 presents each of the 25 hotspots for animal-vehicle collision crashes with a potential name, mile marker beginning and end points, length, and the rate of crashes per mile over the 10 years of data for each hot spot. The rankings were based on the number of animal-vehicle collision reported crashes per mile over the 10 years of crash data (2007-2016). The top crash hotspot location had 14.42 animal-vehicle collision crashes per mile over the 10 years (1.44 crashes per mile per year). The 25th hotspot had 6.48 crashes per mile over the 10 years (0.65 crashes per mile per year). Table 17 describes the species involved in each hotspot. There were hotspots where the majority of the crashes in those hotspots were caused by mule deer, by elk, by horses, by cattle, and by burros, as well as those with a mix of various animals.

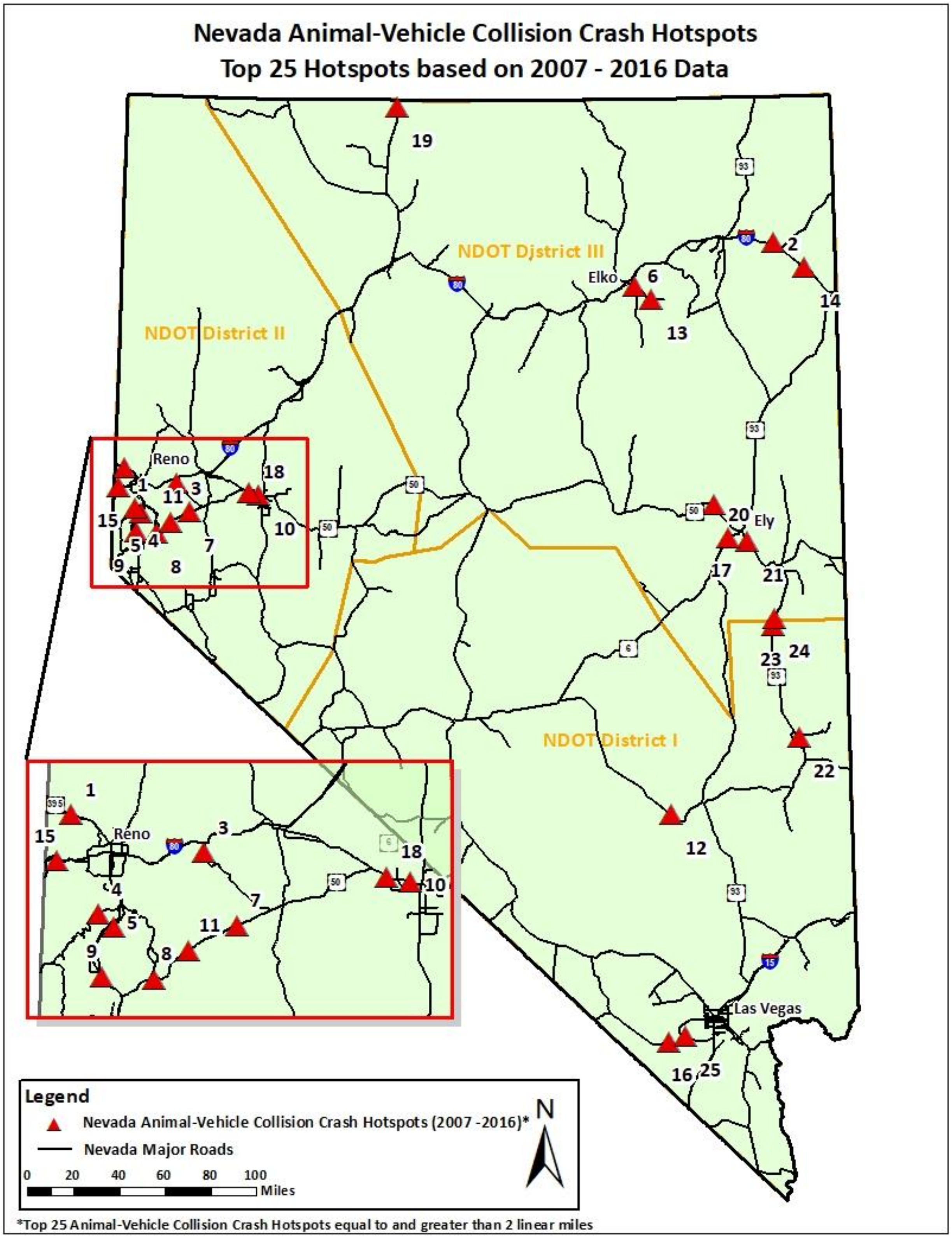


Figure 22. Map of Nevada's Top 25 Priority Reported Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles Long, Based on 2007-2016 Data, Derived From Getis-Ord Analysis 95 Percent and Greater Confidence Intervals.

Table 16. Nevada's Top 25 Animal-Vehicle Collision Crash Hot Spots Greater Than or Equal to Two Miles In Length, Based on Nevada Department of Transportation 2007-2016 Crash Data and Getis-Ord Gi* Analysis 95 Percent and Greater Confidence Intervals.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots.

Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
1	US 395	US 395 Granite Peak	WA 34	WA 38	4.09	59	14.42	II
2	I-80	I-80 Pequop Summit	EL 94	EL 100	6.07	82	13.51	III
3	SR 439	USA Highway Clark Mountain	ST 7	ST 10	3.02	34	11.26	II
4	SR 431	SR 431 Mount Rose Foothills	WA 17	WA 22	5.02	46	9.17	II
5	US 395A	US 395A Pleasant Valley	WA 10	WA 13.5	3.52	31	8.80	II
6	SR 227	SR 227 Elko Hills	EL 2	EL 6	4.02	34	8.47	III
7	US 50	US 50 Horse Fence End	LY 19.5	LY 21.5	2.01	17	8.47	II
8	US 50/ SR 341	US 50 Dayton	US 50 CC 16	US 50 CC 16.6	7.37	58	7.87	II
			US 50 LY 0	US 50 LY 5.5				
			SR 341 LY 0	SR 341 LY 1				
		Note that US 50 MM 16 is in Carson City County and occurs just west of the Lyon County zero reset for MM and the hotspot also includes one mile of SR 341						
9	I-580/ US 395A	I-580 & US 395A Southwest Washoe Lake	I-580 CC 8	I-580 CC 9.3	5.72	44	7.70	II
			I-580 WA 0	I-580 WA 2.8				
			US 395A WA 0.7	US 395A WA 2.7				
			SR 877 WA 0	SR 877 WA 0.6				
		Includes all 3 roads on the SW end of Lake Washoe: I-580, US 395A, & SR 877						
10	US 50	US 50 West Fallon	CH 17.5	CH 20	2.50	19	7.60	II
11	US 50	US 50 Carson Plains	LY 10	LY 12	2.00	15	7.49	II
12	SR 375	SR 375 Tikaboo Valley	LN 27.8	LN 31.2	3.50	26	7.43	I
13	SR 227	SR 227 Spring Creek	EL 12.5	EL 16	3.52	26	7.40	III

Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
14	I-80	I-80 Silver Zone	EL 113	EL 116.5	3.53	26	7.36	III
15	I-80	I-80 Stateline to Reno	I-80 WA 1	I-80 WA 8.5	12.29	90	7.32	II
			SR 425 WA 2.8	SR 425 WA 6.8				
		West of Reno to California State Line and, includes I-80 Loop = SR 425 in Verdi						
16	SR 160	SR 160 Mountain Springs	CL 20.5	CL 24	3.55	26	7.32	I
17	US 6	US 6 Western Eagan Range Foothills	WP 28.5	WP 32.5	4.03	29	7.21	III
18	US 50	US 50 Fallon-Ragtown	US 50 CH 12	US 50 CH 15	4.11	29	7.05	II
			SR 117 CH 0	SR 117 CH 1				
		Includes one mile of SR 117, south from intersection						
19	US 95	US 95 Oregon Border	HU 69	HU 71.5	2.50	17	6.80	III
20	US 50	US 50 Eagan Range Robinson Summit	WP 47.75	WP 50.25	2.53	17	6.72	III
21	US 6	US 6 Steptoe Valley Wildlife Management Area	WP 42.75	WP 45.75	3.00	20	6.66	III
22	US 93/SR 321	US 93 Pioche	US 93 LN 114	US 93 LN 122.5	15.13	100	6.61	I
			SR 321 LN 0	SR 321 LN 5.1				
			SR 322 LN 0	SR 322 LN 1.75				
			SR 320 LN 10	SR 320 LN 10.5				
		Includes SR 321 and US 93 Intersections with SR 320 & SR 322						
23	US 93	US 93 Wambolt Springs	LN 168.25	LN 172.25	4.00	26	6.50	I
24	US 93	US 93 Travis Reservoir	WP 0	WP 2	2.00	13	6.49	III
25	SR 159/SR 160	SR 159 Blue Diamond	SR 159 CL 0	SR 159 CL 7	9.72	63	6.48	I
			SR 160 CL 10.5	SR 160 CL 12.75				
		Includes Approximately Two Miles of SR 160 at Intersection						

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

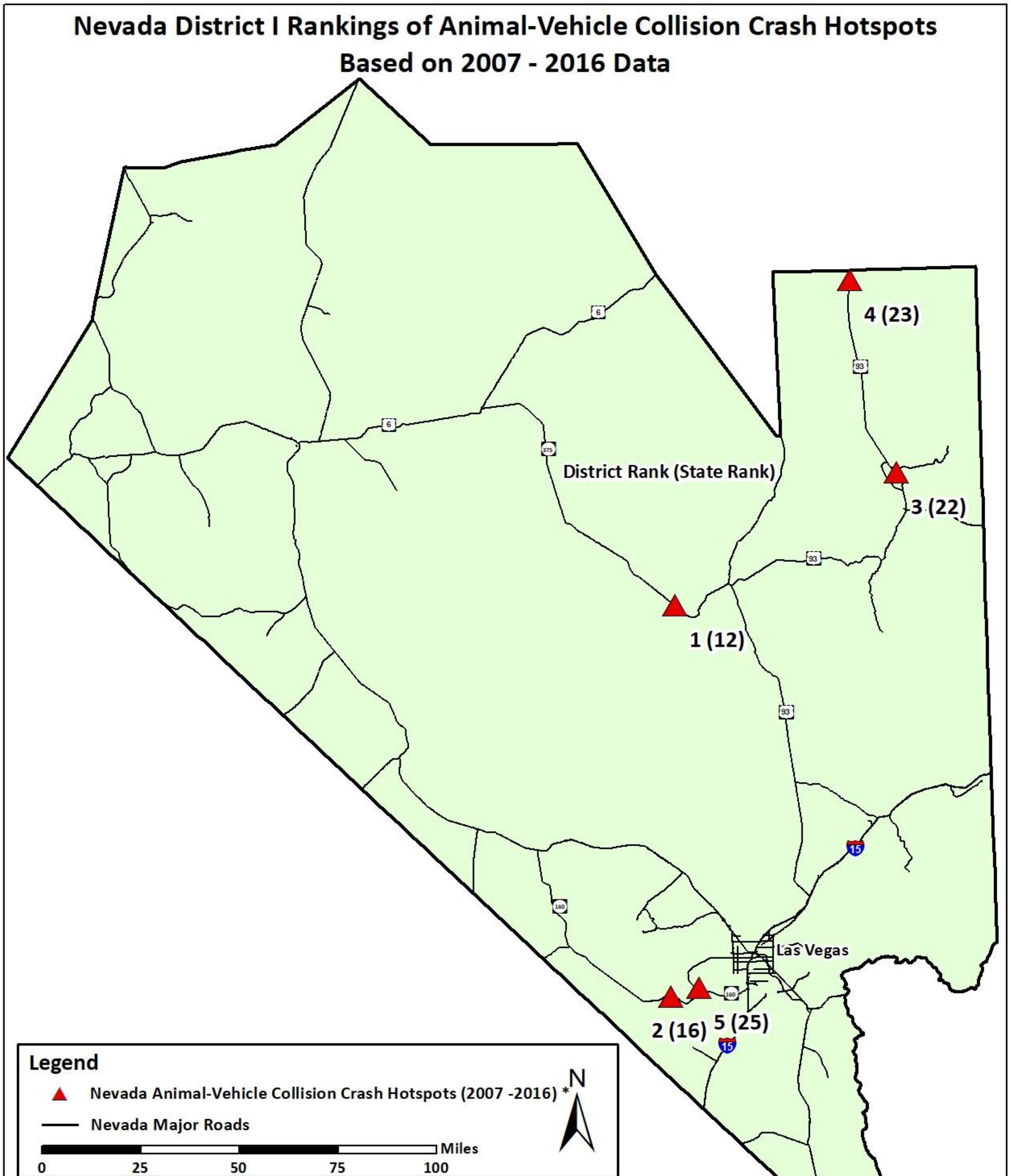
Table 17. Description of Animals Involved in Nevada's Top 25 Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles in Length, Based on 2007-2016 Nevada Department of Transportation Crash Data.

Yellow Shading = NDOT District I	*Green = NDOT District II*	*Pale Blue = NDOT District III*

Rank	Name	Notes on Species, Mitigation, Landscape Factors
1	US 395 Granite Peak	Mule deer were involved in 55 out of 59 crashes. Dog/coyote were the remaining crashes. Water north of the road may be part of the need for mule deer to move.
2	I-80 Pequop Summit	Two Overpasses, fencing to existing 2 bridges & 2 culverts placed in 2017. 98 percent of crashes were with mule deer.
3	USA Highway Clark Mountain	Horses were involved in 30 of the 34 recorded crashes. Highest priority horse crash hotspot in state.
4	SR 431 Mount Rose Foothills	Mule deer were 42 of 46 crashes. There were 2 horses, and one bear involved in AVC. MM 19 has most crashes, but there is no MM 18 in GIS file, so many be administrative.
5	US 395A Pleasant Valley	Both 395, and I-80. Diversity of species. Number one was mule deer, but there were also 7 horse crashes, two cattle, two bear, and one dog/coyote crash. 395, MM 13 is number 16 horse hotspot, MM 11 is the 25 hotspot for horses.
6	SR 227 Elko Hills	Out of 34 crashes, deer are listed involved in 24. Two dog/coyote, and two cattle crashes. Others unknown or not listed.
7	US 50 Horse Fence End	All 17 reported crashes were with horses. Number 3 horse hotspot.
8	US 50 Dayton	Majority of crashes were horses, Deer crashes = 12; 3 dog/coyote. Number 2 horse crash hotspot. Hotspot includes first mile north on SR 341.
9	I-580 & US 395A South Washoe Lake	Diverse animal species: Deer=37 crashes, Bear=3, Coyote/dog=3, mountain lion=1. Major wildlife movement linkage from mountains to foothills and water. Number 5 wildlife hotspot.
10	US 50 West Fallon	Deer are 15 out of 19 crash involved animals. Two cattle, two dog/coyote crashes. The majority of crashes occurred near the canal on the west side of town, where Coleman and Casey Roads bisect US 50.
11	US 50 Carson Plains	Horses were involved in 12 out of 15 crashes. One deer and 3 dog/coyote crashes were the other animal types.
12	SR 375 Tikaboo Valley	Cattle were involved in 24 out of 26 crashes. Top cow hotspot in state. One pronghorn. Open Range
13	SR 227 Spring Creek	South of Elko, Deer crashes were 23 out of 26 crashes. Dog/coyote were three crashes.
14	I-80 Silver Zone	Wildlife Overpass, Fencing to Two Bridges Placed in 2013. Mule deer were involved in 23 of 26 crashes, one dog/coyote, two elk. A major mule deer migration linkage.
15	I-80 Stateline to Reno	Out of 90 crashes, mule deer were involved in 72 crashes, 4 bear, 4 dog/coyote, 1 cattle, 1 bird, 2 unknown animals. The

Yellow Shading = NDOT District I		Green = NDOT District II / Pale Blue = NDOT District III
Rank	**Name**	**Notes on Species, Mitigation, Landscape Factors**
		location is a biodiverse area with mountains, foot hills, and the Truckee River running along the highway.
16	SR 160 Mountain Springs	Of the 26 crashes were the species was identified, 20 were with mule deer, three were with elk, two dog/coyote, and one burro crash. NDOT has a wildlife crossing structure schedule to be built at this site in 2019.
17	US 6 Western Eagan Range Foothills	This mountainous area has three ungulate species killed: 1 bighorn sheep, 1 cattle, 5 elk, and 22 mule deer.
18	US 50 Fallon-Ragtown	Of the 32 crashes in the area, 20 were with mule deer. There were 7 dog/coyote and five cattle crashes.
19	US 95 Oregon Border	Cattle were involved in 16 out of 17 crashes. One horse. Number 2 cattle hotspot in state
20	US 50 Eagan Range Robinson Summit	The is predominantly a mule deer hotspot: all but one crash were mule deer. The other crash was with an elk.
21	US 6 Steptoe Valley Wildlife Management Area	This hotspot has three ungulate species killed in crashes: 2 pronghorn, 8 elk, and 11 mule deer. This area is tied for the second highest elk hotspot for crashes.
22	US 93 Pioche	Multiple roads in and out of Pioche, entire area a hotspot for mule deer and horses. The area has 3 of the top horse hotspots.
23	US 93 Wambolt Springs	This is the number 1 elk hotspot in the state: out of 26 crashes, 17 were with elk. Deer = 8 crashes, cattle = one.
24	US 93 Travis Reservoir	This area is tied for the second highest elk crash site: 8 elk crashes, deer=3, one each of pronghorn antelope, cattle, and dog/coyote.
25	SR 159 Blue Diamond	This is the burro hotspot in the state. Out of 66 crashes in the area 56 were with burros, deer were in 7 crashes, one dog/coyote, and two unknown animals. Note this is both SR 159 and SR 160 intersection.

Figures 23, 24, and 25 present where the state top 25 animal-vehicle collision crash hotspots reside in each of NDOT's three districts. Below each figure is a table of these hotspot locations for each district (Tables 18 through 20).



District Rank	Statewide Rank	Road	Mile Marker Start (approx)	Mile Marker Finish (approx)	Length (miles)	Number of Incidents	Incidents per Mile
1	12	SR 375	28	31	3.501	26	7.426
2	16	SR 160	21	24	3.551	26	7.322
3	22	US 93 / SR 321	114	122.5	15.129	100	6.610
4	23	US 93	168.5	172.25	4.002	26	6.497
5	25	SR 159	1	7	9.721	63	6.481

*Top 25 Animal-Vehicle Collision Crash Hotspots greater than 2 linear miles

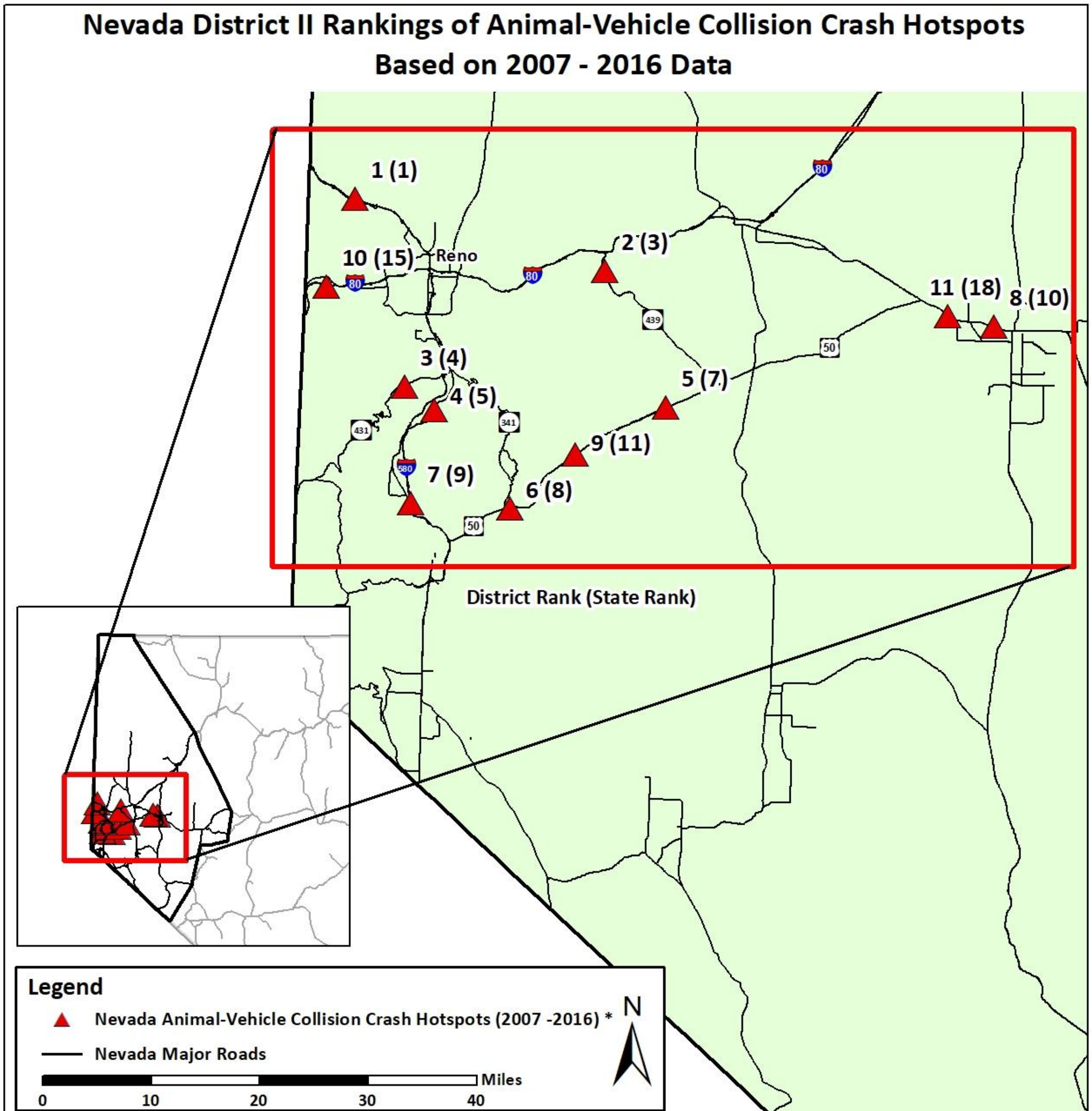
Figure 23. Location of Top 25 State Priority Animal-Vehicle-Collision Crash Hotspots Equal to Or Greater Than Two Miles in Length Within Nevada Department of Transportation District I, 2007-2016.

First Rank is District Rank, Second Number is for Within Nevada State Ranking.

Table 18. Nevada Department of Transportation District I Top Hotspots of Animal-Vehicle Collision Crashes Equal to or Greater Than Two Miles in Length Out of State Top 25 Priority Hotspots, Based on 2007-2016 Crash Data.

District Rank	State Rank	Potential Name	Road	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
1	12	SR 375 Tikaboo Valley	SR 375	LN 28	LN 31	3.50	26	7.43
2	16	SR 160 Mountain Springs	SR 160	CL 21	CL 24	3.55	26	7.32
3	22	US 93 Pioche	US 93 / SR 321	US 93 LN 114	US 93 LN 122.5	15.13	100	6.61
				SR 321 LN 0	SR 321 LN 5.1			
				SR 322 LN 0	SR 322 LN 1.75			
				SR 320 LN 10	SR 320 LN 10.5			
		Includes SR 321 and US 93 Intersections with SR 320 & SR 322						
4	23	US 93 Wambolt Springs	US 93	LN 168.5	LN 172.25	4.00	26	6.40
5	25	SR 159 Blue Diamond	SR 159/ SR 160	SR 159 CL 0	SR 159 CL 7	9.72	63	6.48
				SR 160 CL 10.5	SR 160 CL 12.75			
		Includes Approximately Two Miles of SR 160 at Intersection						

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CL=Clark, LN=Lincoln.*



District Rank	Statewide Rank	Road	Mile Marker Start (approx)	Mile Marker Finish (approx)	Length (miles)	Number of Incidents	Incidents per Mile
1	1	US 395	34	38	4.092	59	14.418
2	3	SR 439	7	10	3.021	34	11.255
3	4	SR 431	17	22	5.019	46	9.165
4	5	US 395A	10	13.5	3.522	31	8.803
5	7	US 50	19.5	22.5	2.008	17	8.466
6	8	US 50	16	6	7.370	58	7.869
7	9	I 580	2.78	7.96	5.716	44	7.698
8	10	US 50	17	20	2.502	19	7.595
9	11	US 50	10	12	2.003	15	7.490
10	15	I 80	1	8.5	12.289	90	7.324
11	18	US 50	12	15	4.112	29	7.052

*Top 25 Animal-Vehicle Collision Crash Hotspots greater than 2 linear miles

Figure 24. Location of Top State Priority Animal-Vehicle-Collision Crash Hotspots Equal to or Greater Than Two Miles in Length, Within Nevada Department of Transportation District II, 2007-2016.

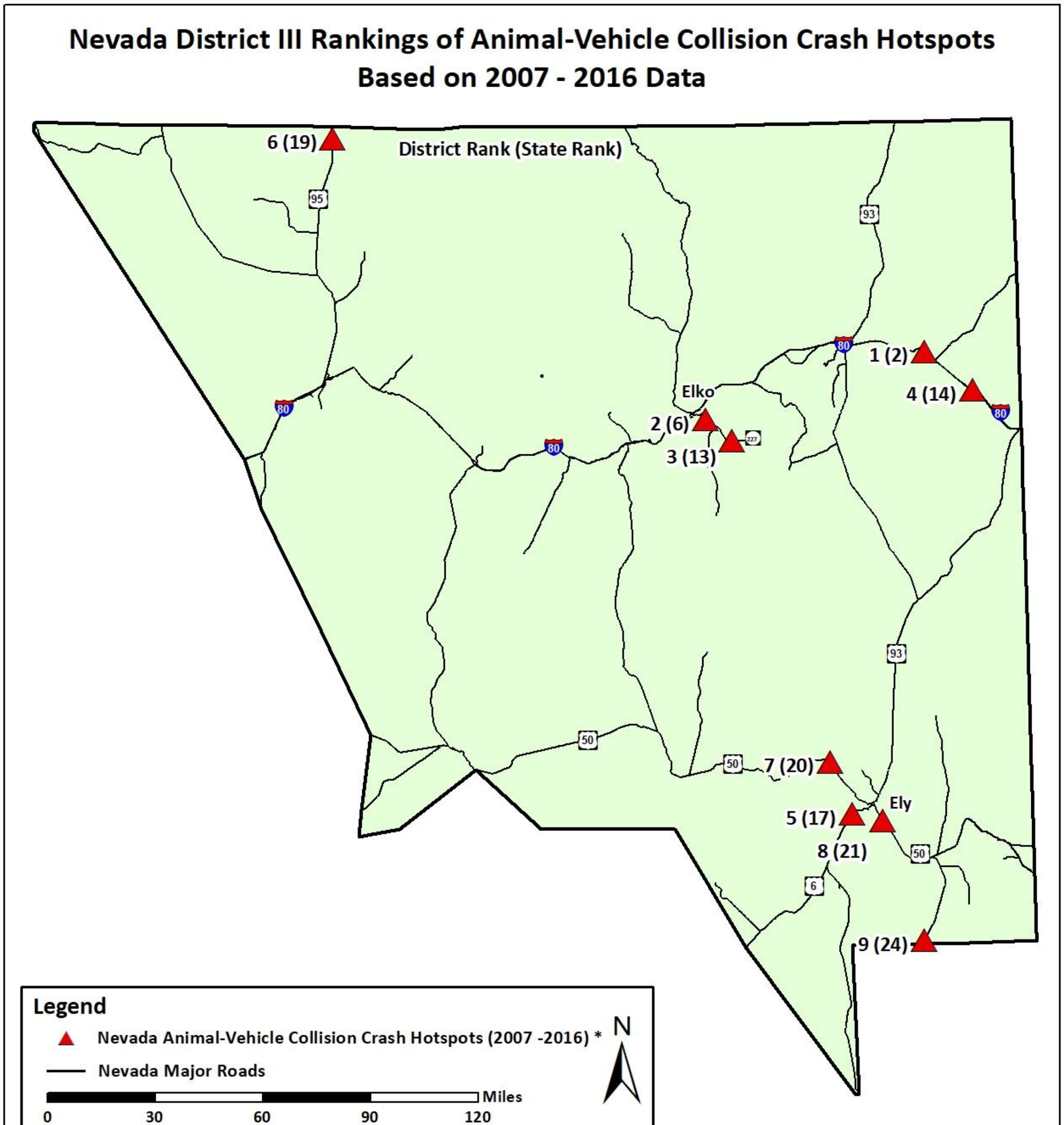
First Rank is District Rank, Second Number is for Within Nevada State Ranking.

Table 19. Nevada Department of Transportation District II Top Hotspots of Animal-Vehicle Collision Crashes Equal to or Greater Than Two Miles in Length, Out of State Top 25 Priority Hotspots, Based on 2007-2016 Crash Data.

District Rank	State Rank	Potential Name	Road	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes / Mile/ 10 Years
1	1	US 395 Granite Peak	US 395	WA 34	WA 38	4.09	59	14.42
2	3	USA Highway Clark Mountain	SR 439	ST 7	ST 10	3.02	34	11.26
3	4	SR 431 Mount Rose Foothills	SR 431	WA 17	WA 22	5.20	46	9.17
4	5	US 395A Pleasant Valley	US 395A	WA 10	WA 13.5	3.52	31	8.80
5	7	US 50 Horse Fence End	US 50	LY 19.5	LY 22.5	2.01	17	8.47
6	8	US 50 Dayton	US 50/SR 341	US 50 DO 16	US 50 DO 16.6	7.37	58	7.87
				US 50 LY 0	US 50 LY 5.5			
				SR 341 LY 0	SR 341 LY 1			
		US 50 MM 16 is in Carson City County and occurs just west of the Lyon County zero reset for MM and the hotspot also includes one mile of SR 341						
7	9	I-580 & US 395A Southwest Washoe Lake	I-580 /US 395A	I-580 CC 8	I-580 CC 9.3	5.72	44	7.70
				I-580 WA 0	I-580 WA 2.8			
				US 395A WA 0.7	US 395A WA 2.7			
				SR 877 WA 0	SR 877 WA 0.6			
		Includes all 3 roads on SW end of Lake Washoe: I-580, US 395A, & SR 877						
8	10	US 50 West Fallon	US 50	CH 17	CH 20	2.50	19	7.60
9	11	US 50 Carson Plains	US 50	LY 10	LY 12	2.00	15	7.49
10	15	I-80 Stateline to Reno	I 80	I-80 WA 1	I-80 WA 8.5	12.29	90	7.32

District Rank	State Rank	Potential Name	Road	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes / Mile/ 10 Years
				SR 425 WA 2.8	SR 425 WA 6.8			
		West of Reno to California State Line, includes I-80 Loop = SR 425 in Verdi						
11	18	US 50 Fallon-Ragtown	US 50/ SR 117	US 50 CH 12	US 50 CH 15	4.11	29	7.05
				SR 117 CH 0	SR 117 CH 1			
		Includes one mile of SR 117, south from intersection						

** Mile Markers Name Include Abbreviation for County Which Mile Markers Occur In. CC=Carson City, CH=Churchill, DO=Douglas, LY=Lyon, ST=Storey, and WA=Washoe.*



District Rank	Statewide Rank	Road	Mile Marker Start (approx)	Mile Marker Finish (approx)	Length (miles)	Number of Incidents	Incidents per Mile
1	2	I 80	94	100	6.072	82	13.505
2	6	SR 227	2	6	4.015	34	8.468
3	13	SR 227	12.5	16	3.516	26	7.396
4	14	I 80	113	116.5	3.534	26	7.356
5	17	US 6	28.5	32.5	4.025	29	7.205
6	19	US 95	69	71.5	2.501	17	6.797
7	20	US 50	47.75	51.25	2.530	17	6.720
8	21	US 6	46.5	43.25	3.003	20	6.661
9	24	US 93	0	2	2.003	13	6.491

*Top 25 Animal-Vehicle Collision Crash Hotspots greater than 2 linear miles

Figure 25. Location of Top State Priority Animal-Vehicle-Collision Crash Hotspots Equal to or Greater Than Two Miles in Length within Nevada Department of Transportation District III, 2007-2016.

First Rank is District Rank, Second Number is for Within Nevada State Ranking.

Table 20. Nevada Department of Transportation District III Top Hotspots of Animal-Vehicle Collision Crashes Equal to or Greater Than Two Miles in Length Out of State Top 25 Priority Hotspots, Based on 2007-2016 Crash Data.

District Rank	State Rank	Potential Name	Road	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
1	2	I-80 Pequop Summit	I 80	EL 94	EL 100	6.07	82	13.51
2	6	SR 227 Elko Hills	SR 227	EL 2	EL 6	4.02	34	8.47
3	13	SR 227 Spring Creek	SR 227	EL 12.5	EL 16	3.52	26	7.40
4	14	I-80 Silver Zone	I 80	EL 113	EL 116.5	3.53	26	7.36
5	17	US 6 Western Eagan Range Foothills	US 6	WP 28.5	WP 32.5	4.03	29	7.21
6	19	US 95 Oregon Border	US 95	HU 69	HU 71.5	2.50	17	6.80
7	20	US 50 Eagan Range Robinson Summit	US 50	WP 47.75	WP 51.25	2.53	17	6.72
8	21	US 6 Steptoe Valley Wildlife Management Area	US 6	WP 46.5	WP 43.25	3.00	20	6.66
9	24	US 93 Travis Reservoir	US 93	WP 0	WP 2	2.00	13	6.49

** Mile Markers Name Include Abbreviation for County Which Mile Markers Occur In. EL=Elko, HU=Humboldt, and WP= White Pine.*

Nevada 25 Priority Hot Spots for Animal-Vehicle Collision Crashes Segments Under Two Miles Long

The Getis-Ord analyses of the top crash locations also produced priority road segments that were less than two miles long. They were not included with the master 25 top priorities because their length was not comparable to the longer segments. They are included here to help NDOT and NDOW staff pinpoint problem areas in each NDOT district (Figure 26). These are very specific spots where animals were getting killed, and thus, solutions to reducing these crashes may be very specific in location (see Table 21). Many are within a mile of the top 25 hot spots longer than two miles.

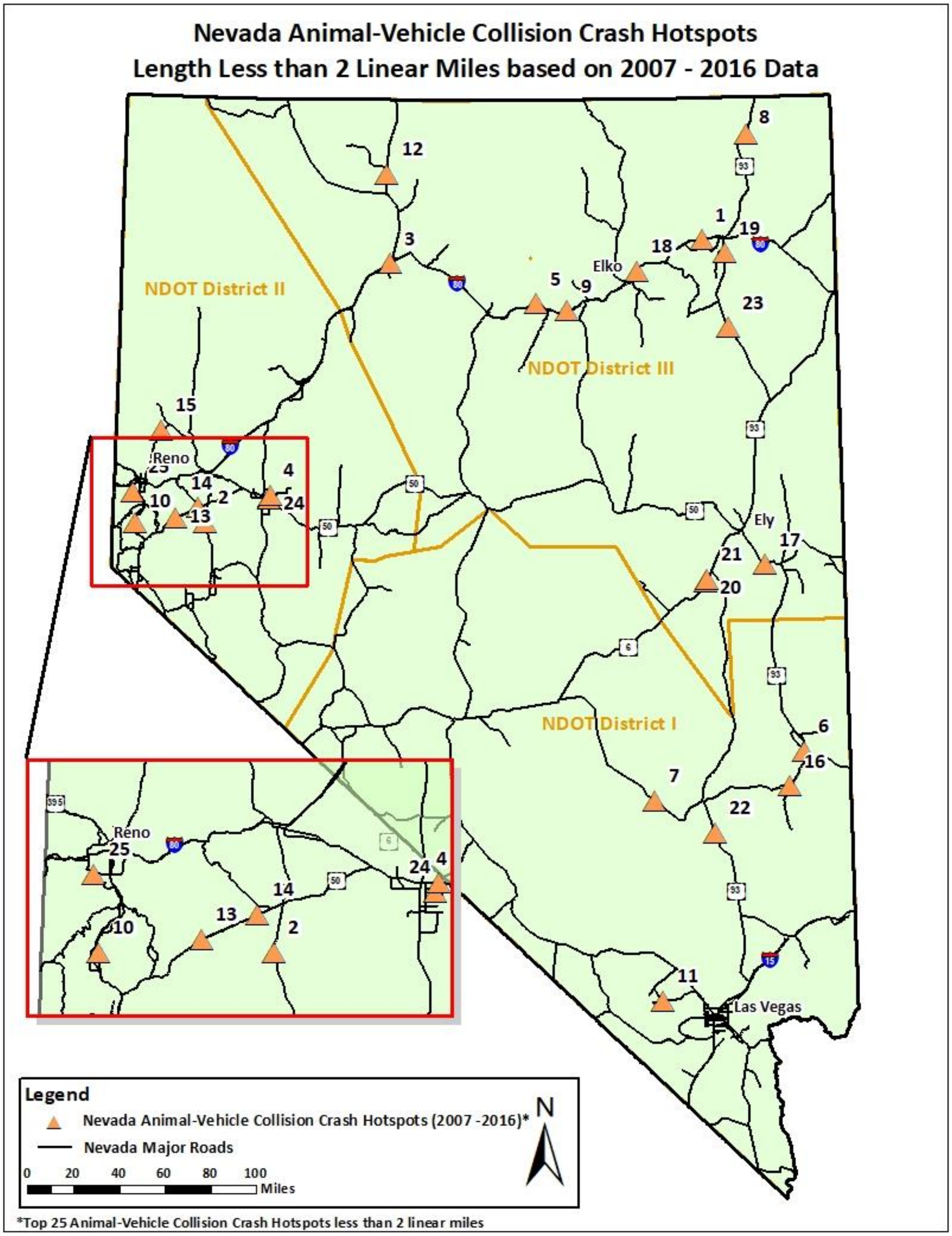


Figure 26. Nevada Top 25 Priority Animal-Vehicle Collision Crash Hot Spots Less Than Two Miles in Length, Nevada Department of Transportation 2007-2016 Crash Data and Getis-Ord Gi* Analysis 95 Percent and Greater Confidence Intervals.

Table 21. Top 25 Animal-Vehicle Collision Crash Hotspots In Nevada Less Than Two Miles Long, from 2007-2016, Nevada Department of Transportation Crash Data and Getis-Ord Gi* Analysis 95 Percent and Greater Confidence Intervals.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots.

Rank	Road	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Incidents	Crashes/ Mile/10 Years	District
1	I-80	EL 63.5	EL 64	0.52	5	9.69	III
2	US 95A	LY 34.4	LY 36.25	1.50	14	9.31	II
3	I-80	HU 12	HU 13.5	1.51	15	9.25	III
4	US 50	CH 23.25	CH 24.25	1.00	9	9.00	II
5	I-80	EU 3	EU 3.19	0.24	2	8.52	III
6	US 93	LN 10.5	LN 11.5	1.00	8	8.00	I
7	SR 375	LN 20.5	LN 21	0.50	4	8.00	I
8	US 93	EL 125	EL 125.5	0.50	4	8.00	III
9	I-80	EU 17.75	EU 18.25	0.51	4	7.90	III
10	I-580	WA 5.25	WA 6.75	0.51	4	8.00	II
11	SR 157	CL 5	CL 5.5	0.52	4	7.74	III
12	US 95	HU 39.5	HU 41	1.50	11	7.33	III
13	US 50	LY 13	LY 14.5	1.50	11	7.33	II
14	US 50	LY 24	LY 25	1.00	7	7.00	II
15	SR 445	WA 24.5	WA 26	1.50	10	6.66	II
16	US 93	LN 91.5	LN 93.25	1.51	10	6.64	I
17	US 6	WP 56.5	WP 58.25	1.52	10	6.60	III
18	I-80	EL 30	EL 31	0.93	6	6.47	III
19	US 93	EL 67.5	EL 68	0.50	3	6.00	III
20	US 6	WP 8	WP 8.5	0.50	3	6.00	III
21	US 6	WP 8.5	WP 10	1.50	9	5.99	III
22	US 93	LN 36	LN 36.5	0.50	3	5.99	I
23	US 93	EL 32.5	EL 34	1.50	9	5.99	III
24	SR 118	CH 1.5	CH 2	0.50	3	5.97	II
25	SR 659	WA 2.5	WA 3	0.50	3	5.96	II

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

Horse and cattle crash data were mapped with the Getis-Ord statistic hotspot mapping tool for each species' specific statewide priority hotspots, see Figures 27 and 28. Tables were created to identify those top 25 hotspot locations for horses (Table 22), and cattle (Table 23).

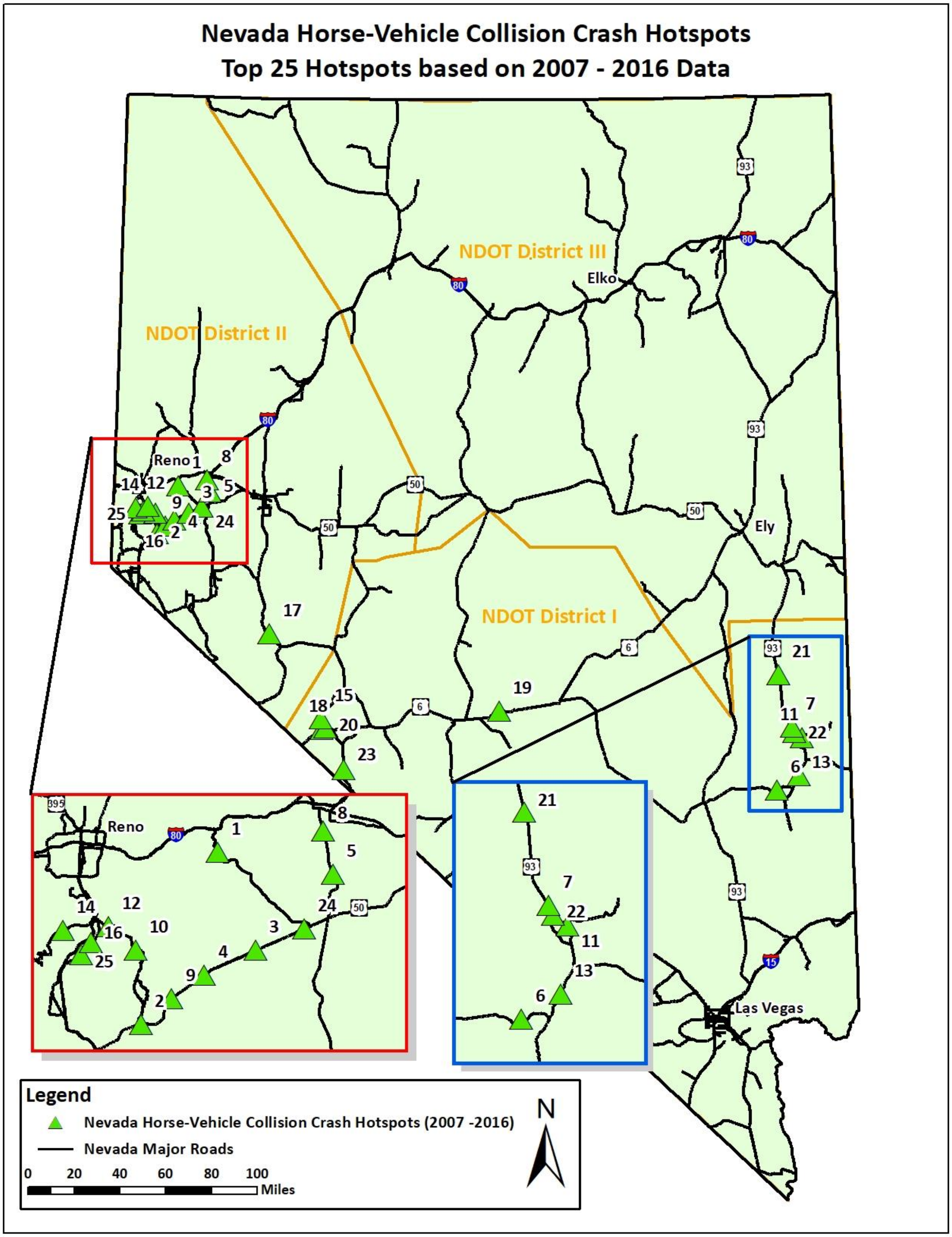


Figure 27. Top 25 Priority Reported Horse-Vehicle Collision Crash Hotspots for Nevada, Based on 2007-2016 Data.

Table 22. Nevada's Top 25 Horse-Vehicle Collision Crash Hot Spots Based on Nevada Department of Transportation 2007-2016 Crash Data and Getis-Ord Gi* Analysis 95 Percent and Greater Confidence Intervals.

Yellow Shading = NDOT District I, and Green = District II, Hot Spots

Rank	Road	Potential Name	~ Mile Marker Start *	~ Mile Marker Finish *	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
1	SR 439 & I-80	USA Highway I-80 Junction and South & Clark Mountain	SR 439 ST 6 I-80 WA 32	SR 439 ST 10 I-80 WA 32.5	6.46	34	5.26	II
2	US 50 & SR 341	US 50 Dayton	US 50 DO 16 US 50 LY 0 SR 341 LY 0	US 50 DO 16.6 US 50 LY 6 SR 341 LY 2	8.72	43	4.93	II
3	US 50	US 50 Horse Fence End	LY 16.5	LY 23	6.58	27	4.10	II
4	US 50	US 50 Carson Plains	LY 10	LY 15.5	5.52	22	3.98	II
5	US 95A/US 50A	US 50A North of Silver Springs	US 50A LY 5	US 50A LY 7	2.00	6	3.00	II
6	US 93	US 93 Newman Canyon	LN 83	LN 88	5.05	15	2.97	I
7	US 93	US 93 North of Pioche	LN 124	LN 125.5	1.50	4	2.67	I
8	US 95A/US 50A	US 50A South Fernley	US 50A LY 9	US 50A LY 13	4.50	11	2.44	II
9	US 50	US 50 Carson Plains	LY 7	LY 9	2.51	6	2.94	II
10	SR 341	SR 341 Virginia City	SR 341 ST 4	SR 341 ST 10	5.65	12	2.13	II
11	US 93 & SR 322	US 93 East Pioche	IUS 93 LN 116.5 SR 322 0	US 93 LN 119 SR 322 1.8	3.93	8	2.04	I
12	SR 341 & US 95A	SR 341 Steamboat	SR 341 WA 0.5	SR 341 WA 6	6.45	13	2.02	II
13	US 93	US 93 Caliente Meadow Valley	LN 99.3	LN 10.8	1.50	33	2.00	I
14	SR 431	Mount Rose Highway	WA 20	WA 20.5	0.50	1	2.00	II
15	SR 360	SR 360 Candelaria Hills	MI 3.5	MI 5	1.51	3	1.99	I
16	US 395A	US 395A Steamboat Hot Springs	WA 12	WA 14.5	2.51	5	1.99	II
17	US 95	US 95 Walker Lake	MI 56.5	MI 58	1.51	3	1.99	II

Rank	Road	Potential Name	~ Mile Marker Start *	~ Mile Marker Finish *	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
18	US 6/SR 360	US 6 SR 360 Intersection	US 6 MI 11 SR 360 0	US 6 MI 12.2 SR 360 MI 0.5	1.77	3	1.69	I
19	US 6	US 6 Humboldt-Toiyabe National Forest	NY 22.2	NY 24.5	2.50	4	1.60	I
20	US 6	US 6 Mineral Esmerelda County Line	MI 13	MI 15	2.51	4	1.60	I
21	US 93	US 93 Grassy Springs Pioche	LN 148	LN 149.9	1.94	3	1.55	I
22	US 93/SR 320	US 93 North Pioche	US 93 121.5 SR 320 LN 9.5	US 93 123 SR 320 10.5	2.59	4	1.55	I
23	SR 264	SR 264 Fish Lake Valley	ES 13.5	ES 15	1.50	2	1.33	I
24	US 50/SR 439	US 50 & USA Highway Intersection	LY 23.5 SR 439 14	LY 29 SR 439 15	6.80	9	1.32	II
25	US 395A	US 395A Pleasant Valley	WA 10.5	WA 11.5	1.01	1	0.99	II

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, ES=Esmeralda, HU=Humboldt, MI = Mineral, LN=Lincoln, LY=Lyon, PE= Pershing, ST=Storey, WA=Washoe, and WP= White Pine.*

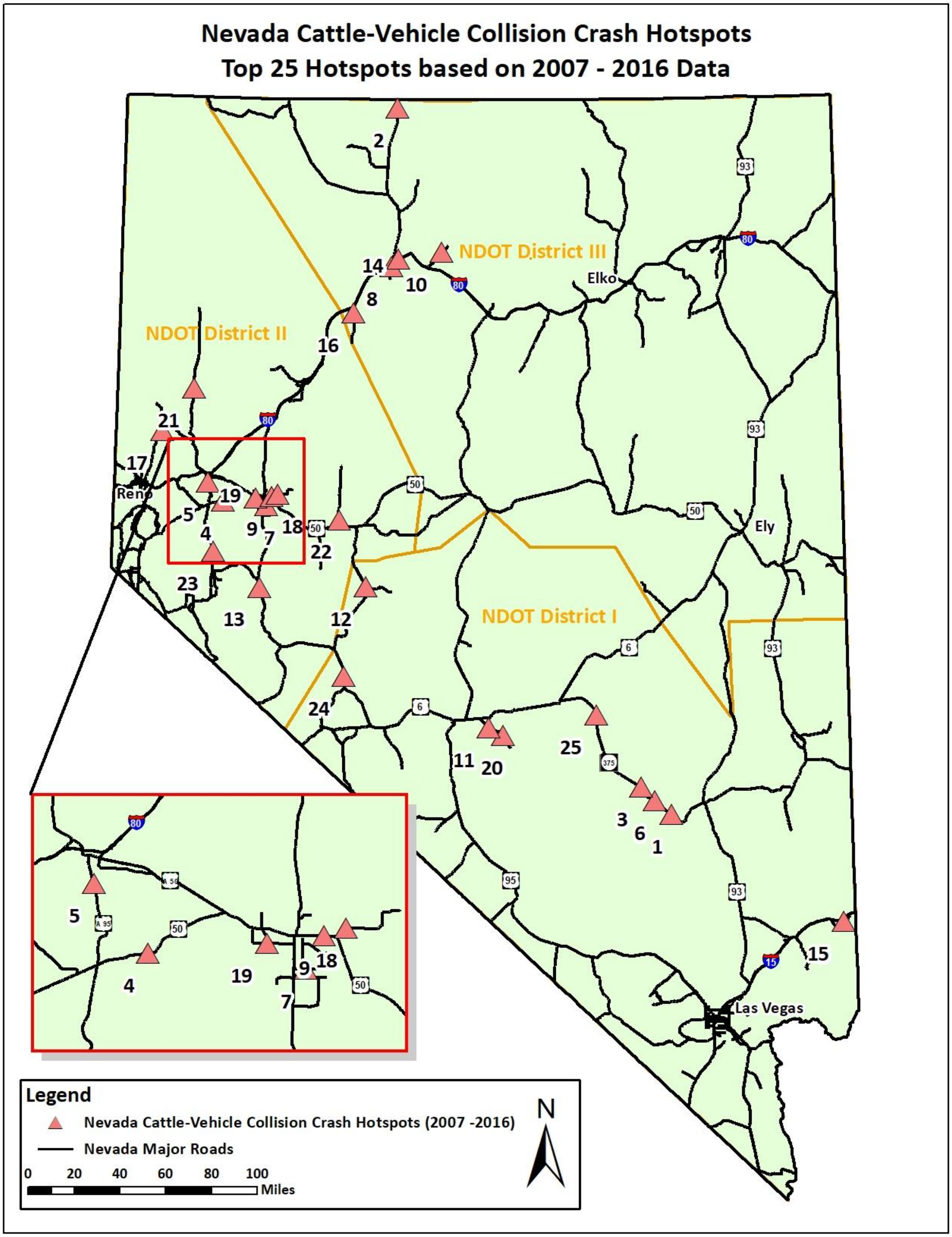


Figure 28.Nevada Top 25 Hotspots for Reported Cattle-Vehicle Collision Crashes, 2007-2016.

Table 23. Nevada's Top 25 Cattle-Vehicle Collision Crash Hot Spots Based on Nevada Department of Transportation 2007-2016 Crash Data and Getis-Ord Gi* Analysis 95 Percent and Greater Confidence Intervals.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots

Rank	Road	Potential Name	~ Mile Marker Start *	~ Mile Marker Finish *	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
1	SR 375	Extra Terrestrial Highway South Tikaboo Valley	LN 27	LN 31.8	5.00	28	5.60	I
2	US 95	US 95 Oregon Border	HU 69	HU 72	3.00	16	5.33	III
3	SR 375	Extra Terrestrial Highway North Tikaboo Valley	LN 9.5	LN 12	2.50	12	4.80	I
4	US 50	US 50 Lahontan Reservoir	CH 1 LY 33	CH 4 LY 35	6.52	28	4.30	II
5	US 50A/US 95A	US 50A & US 95A South Fernley	LY 9	LY 12	4.00	15	3.75	II
6	SR 375	Extra Terrestrial Highway Mid Tikaboo Valley	LN 16	LN 24	8.01	27	3.37	I
7	SR 270 & SR 115	SR 270 & 115 South Side of Fallon	SR 270 CH 1 SR 115 CH 1	SR 270 CH 2 SR 115 CH 1.5	1.50	5	3.33	II
8	SR 294	Grass Valley Road South Winnemucca	HU 5.5	HU 7	1.50	5	3.33	III
9	US 50	US 50 East Side of Fallon	CH 23	CH24.5	1.50	5	3.33	II
10	SR 789	SR 789 Getchel Road-Kelly Creek	HU 9	HU15	6.50	21	3.22	III
11	ARNY 44	ARNY 44 Ralston Valley	NY 14	NY 14	1.00	3	3.00	I
12	SR 361	SR 361 North Gabbs	NY 11.5	NY 12.5	1.00	3	3.00	I
13	US 95	US 95 Walker River	MI 80	MI 82	2.00	6	3.00	II
14	I-80	I-80 East Winnemucca	HU 16.5	HU 17	0.70	2	2.87	III
15	SR 170	SR 170 Mesquite	CL 5	CL 8	4.00	11	2.75	I
16	SR 400	SR 400 Dunn Glenn Flat	PE 11	PE 14	3.50	9	2.57	I
17	SR 445	SR 445 South Pyramid Lake	WA 23.5	WA 28	4.51	11	2.44	II

Rank	Road	Potential Name	~ Mile Marker Start *	~ Mile Marker Finish *	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
18	US 50 & SR 116	US 50 & SR 116 Fallon-Harmon Reservoir	US 50 CH 25 SR 116 0	US 50 CH 27 SR 116 3	5.41	13	2.40	II
19	SR 117	SR 117 West Edge of Fallon	SR 117 CH 3	SR 117 CH 5	2.80	6	2.15	II
20	ARNY 44	ARNY 44 Monitor Hills	NY 6	NY 7	1.50	3	2.00	I
21	SR 447	SR 447 East Pyramid Lake	WA 39	WA 39	0.50	1	2.00	II
22	SR 121	SR 121 Dixie Valley	CH 3	CH 3.5	0.50	1	2.00	II
23	US 50A/US 95A	US 50A & US 95A Wabuska	LY 22	LY 23	0.50	1	2.00	II
24	US 95	US 95 South Mina	MI 11	MI 13	2.00	4	2.00	II
25	SR 375	Extra Terrestrial Highway Railroad Valley	NY 19.5	NY 20.5	1.00	2	2.00	I

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, MI = Mineral, LN=Lincoln, LY=Lyon, PE= Pershing, ST=Storey, WA=Washoe, and WP= White Pine.*

The wildlife-vehicle collision crash hotspots from 2007 through 2016 that were greater than or equal to two miles in length were mapped with Getis-Ord hotspot mapping, Figure 29. Each of the Nevada top 25 Wildlife-Vehicle Collision crash hotspots greater than or equal to two miles in length was named and the statistics on hotspot locations, lengths, number of crashes, crashes per mile, and NDOT district numbers are presented in Table 24.

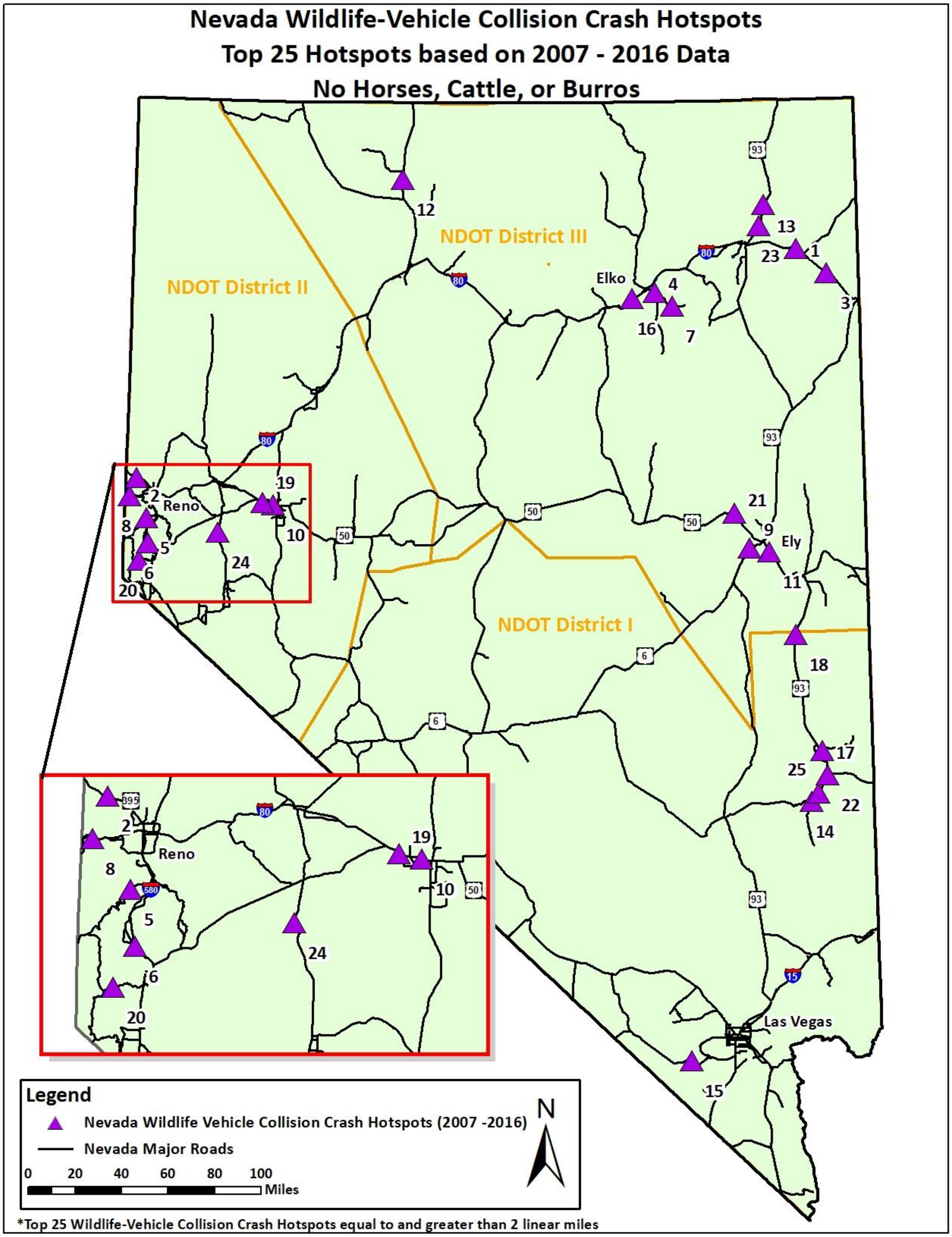


Figure 29. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada 2007-2016, based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros.

Table 24. Nevada Top 25 Wildlife-Vehicle Collision Crash Hotspots Greater Than or Equal to Two Miles in Length. Data Taken from Nevada Department of Transportation 2007-2016 Crash Data. Hotspots Created with Getis-Ord Analysis using 95 percent and Great Confidence Intervals.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots.

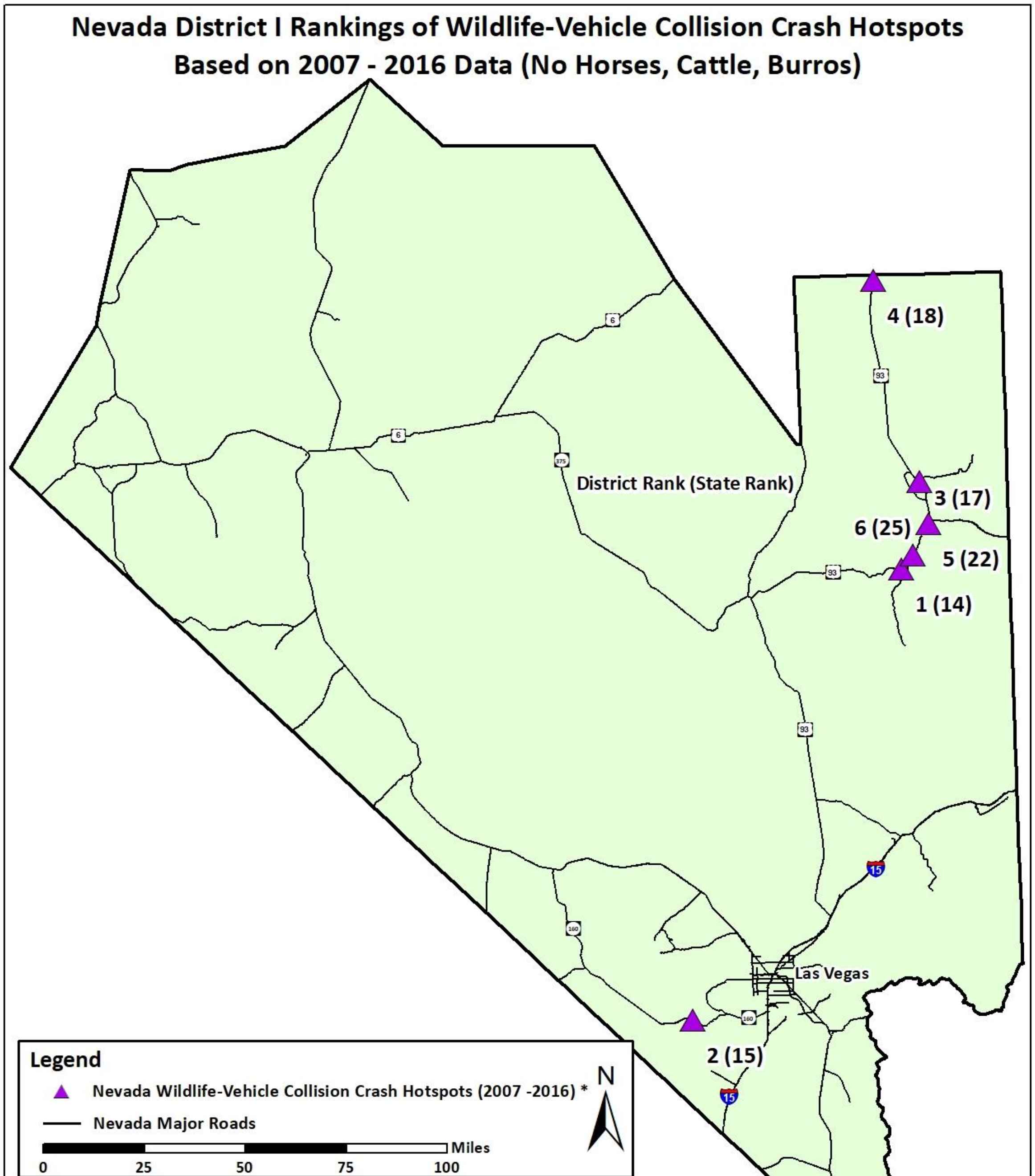
Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
1	I-80	I-80 Pequop Summit	EL 93.8	EL 99.8	6.07	81	13.34	III
2	US 395A	US 395 Granite Peak	WA 33.5	WA 38.75	5.70	64	11.22	II
3	I-80	I-80 Silver Zone	EL 112.5	EL 115	2.52	21	8.31	III
4	SR 227	SR 227 Elko Hills	EL 1.9	EL 5.9	4.01	32	7.97	III
5	SR 431	SR 431 Mount Rose Foothills	WA 16.9	WA 22.4	5.53	43	7.78	II
6	I-580/US 395A	I-580 & US 395A South Washoe Lake	SR 877 WA 0 I-580 CC 7.5 I-580 WA 0 US 395 WA 0	SR 877 WA 0.5 I-580 CC 9.2 I-580 WA 2.7 US 395 WA 2.0	6.18	46	11.22	II
		Includes all 3 roads on the SW end of Lake Washoe: I-580, US 395A, & SR 877						
7	SR227	SR 227 Spring Creek	EL 12.6	EL 16.1	3.516	26	7.40	III
8	I-80	I-80 Stateline to Reno	SR 647 WA 8.5 I-580 WA 0.5 SR 425 WA 2.8	SR 647 WA 9.0 I-580 WA 8.5 SR 425 WA 6.8	12.29	89	7.24	II
		West of Reno to California State Line and, includes I-80 Loop = SR 425 in Verdi						
9	US 6	US 6 Western Eagan Range Foothills	WP 28.5	WP 32.5	4.025	28	6.96	III
10	US 50	US 50 West Fallon	CH 17.5	CH 20	2.502	17	6.80	II
11	US 6	US 6 Steptoe Valley Wildlife Management Area	WP 42.5	WP 45.5	3.00	20	6.66	III
12	US 95	US 95 Quinn River Valley	HU 38.5	HU 41.5	3.00	19	6.33	III

Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
13	US 93	US 93 HD Summit	EL 90	EL96	6.01	37	6.16	III
14	US 93	US 93 Caliente Newman Canyon	LN 91	LN 93	2.01	12	5.97	I
15	SR 160	SR 160 Mountain Springs	CL 18.5	CL 24	5.58	33	5.92	I
16	I-80	I-80 Humboldt River	EL 14.7	EL 17.2	2.54	15	5.90	III
17	US 93/ SR 321	US 93 Pioche	US 93 LN 114 SR 321 LN 0 SR 322 LN 0 SR 320 LN 10	US 93 LN 122.5 SR 321 LN 5.1 SR 322 LN 1.75 SR 320 LN 10.5	15.13	89	5.88	I
		Includes SR 321 and US 93 Intersections with SR 320 & SR 322						
18	US 93	US 93 Wambolt Springs-Travis Reservoir	LN168.2 WP 0	LN 173 WP 2	6.51	38	5.84	I
		All US 93, just crosses two counties						
19	US 50	US 50 Fallon-Ragtown	US 50 CH 12 SR 117 CH 0	US 50 CH 15 SR 117 CH 1	4.11	24	5.84	II
		Intersection of US 50 and SR 117						
20	US 50	US 50 Spooner Summit	US 50 DO 11 US 50 CC 0 SR 28 DO 0	US 50 DO 14.5 US 50 CC 5 SR 28 DO 1	9.64	55	5.71	II
		US 50 in the Mountains west of Carson City, to the intersection with SR 28 and toward Lake Tahoe						
21	US 50	US 50 Eagan Range Robinson Summit	WP 46.7	WP50.2	3.53	20	5.66	III
22	US 93	US 93 Panaca	US 93 LN 104.8 SR 319 LN 0	US 93 LN 108 SR 319 LN 1	5.34	30	5.62	I
		US 93 at the Intersection with SR 319 and Southward						

Rank	Road	Potential Name	~ MM Start*	~MM End*	Length (Miles)	Number of Crashes	Crashes/ Mile/10 Years	District
23	US 93	US 93 Ten Mile Summit	EL 82.5	EL 85	2.50	14	5.59	III
24	US 95A	US 95A Stillwater National Wildlife Refuge	LY 34.6	LY 37.3	2.51	14	5.59	II
25	US 93	US 93 Caliente Meadow Valley	LN 95.8	LN 100.9	5.02	28	5.58	I

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

The Nevada top 25 wildlife-vehicle collision crash hotspots equal to or greater than two miles in length that ocurred in NDOT District I are presented below in Figure 30. Each of the Nevada top 25 Wildlife-Vehicle Collision crash hotspots greater than or equal to two miles in length that occurred in District I are presented in Table 25.



District Rank	Rank	Road	Mile Marker Start	Mile Marker Finish	Length (miles)	Number of Incidents	Normalized Occr.	District	County
1	14	US 93			2.010	12	5.971	District I	Lincoln
2	15	SR 160			5.576	33	5.918	District I	Clark
3	17	SR 322			15.129	89	5.883	District I	Lincoln
4	18	US 93			6.505	38	5.842	District I	Lincoln
5	22	US 93			5.337	30	5.621	District I	Lincoln
6	25	US 93			5.016	28	5.583	District I	Lincoln

*Top NDOT District Wildlife-Vehicle Collision Crash Hotspots greater than 2 linear miles

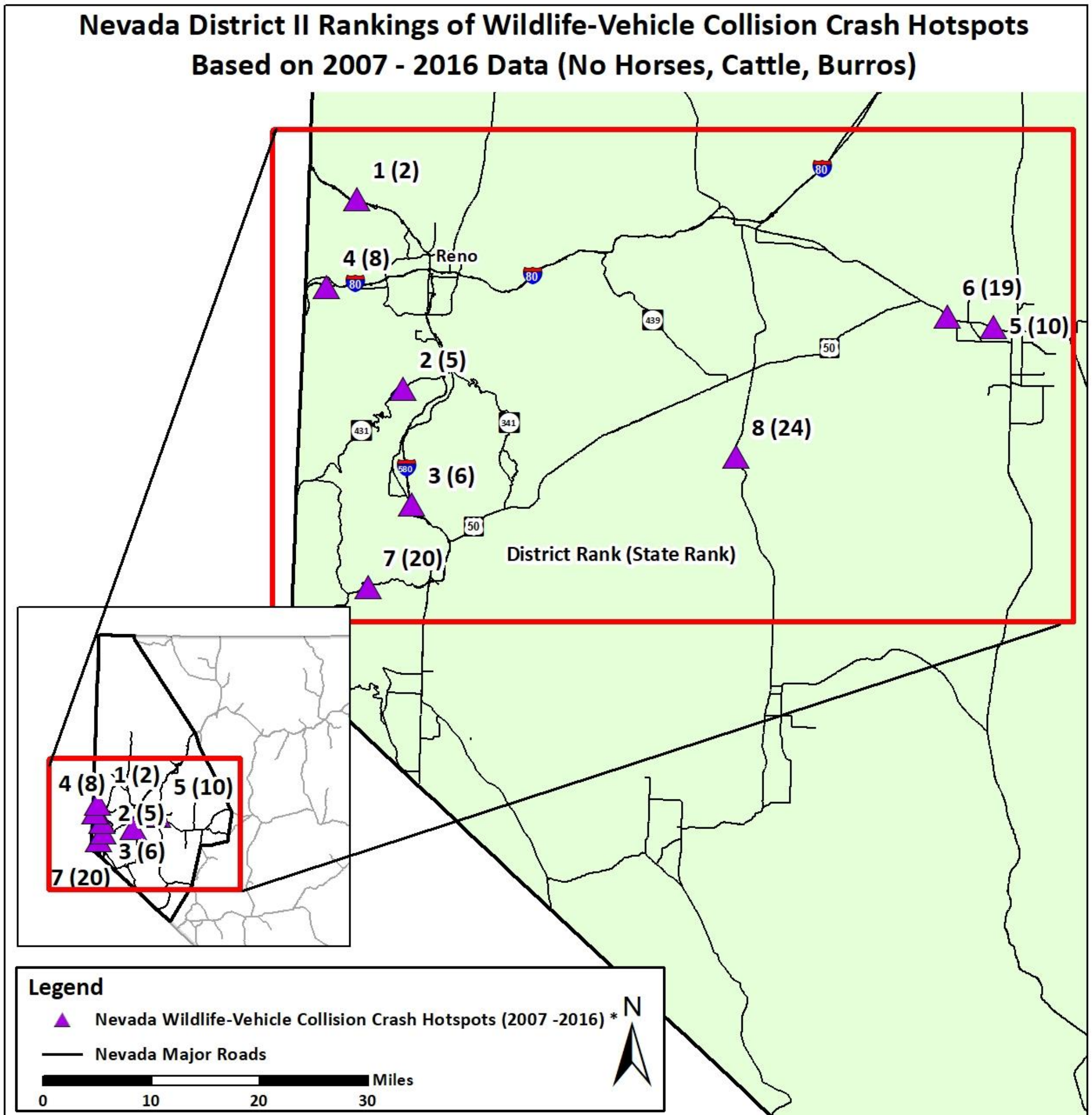
Figure 30. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada That Occurred in NDOT District I 2007-2016, Equal to or Greater Than Two Miles in Length, Based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros.

Table 25. Nevada Department of Transportation District I Top Hotspots of Wildlife-Vehicle Collision Crashes Two or More Miles Long, Out of State Top 25 Priority Hotspots, 2007-2016.

District Rank	State Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
1	14	US 93	US 93 Caliente Newman Canyon	LN 91	LN 93	2.01	12	5.97
2	15	SR 160	SR 160 Mountain Springs	CL 18.5	CL 24	5.58	33	5.92
3	17	US 93/ SR 321	US 93 Pioche	US 93 LN 114 SR 321 LN 0 SR 322 LN 0 SR 320 LN 10	US 93 LN 122.5 SR 321 LN 5.1 SR 322 LN 1.75 SR 320 LN 10.5	15.13	89	5.88
		Includes SR 321 and US 93 Intersections with SR 320 & SR 322						
4	18	US 93	US 93 Wambolt Springs-Travis Reservoir	LN168.2 WP 0	LN 173 WP 2	6.51	38	5.84
		All US 93, just crosses two counties						
5	22	US 93	US 93 Panaca	US 93 LN 104.8 SR 319 LN 0	US 93 LN 108 SR 319 LN 1	5.34	30	5.62
		US 93 at the Intersection with SR 319 and Southward						
6	25	US 93	US 93 Caliente Meadow Valley	LN 95.8	LN 100.9	5.02	28	5.58

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

The Nevada top 25 wildlife-vehicle collision crash hotspots equal to or greater than two miles in length that ocurred in NDOT District II are presented in Figure 31.



District Rank	Rank	Road	Length (miles)	Number of Incidents	Normalized Occr.	District	County
1	2	US 395A	5.704	64	11.219	District II	Washoe
2	5	SR 431	5.528	43	7.778	District II	Washoe
3	6	US 395A	6.175	46	7.449	District II	Washoe
4	8	I 80	12.289	89	7.242	District II	Washoe
5	10	US 50	2.502	17	6.795	District II	Churchill
6	19	US 50	4.112	24	5.836	District II	Churchill
7	20	US 50	9.640	55	5.705	District II	Douglas
8	24	US 95A	2.507	14	5.585	District II	Lyon

*Top District Wildlife-Vehicle Collision Crash Hotspots greater than 2 linear miles

Figure 31. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada That Occurred in NDOT District II 2007-2016, Two or More Miles Long, Based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros.

Each of the Nevada top 25 Wildlife-Vehicle Collision crash hotspots greater than or equal to two miles in length that occurred in District II are presented in Table 26.

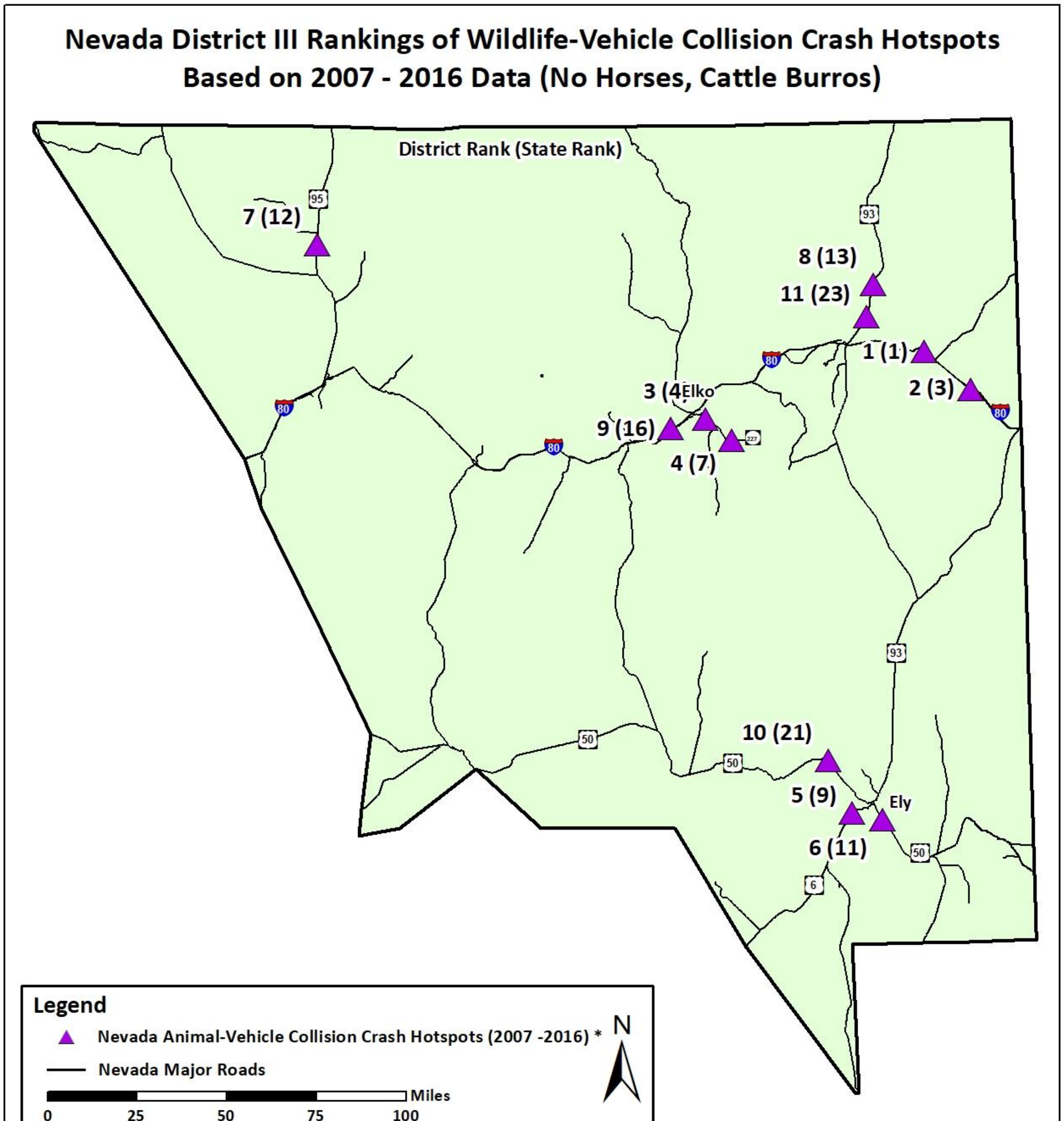
Table 26. Nevada Department of Transportation District II Top Hotspots of Wildlife-Vehicle Collision Crashes Two or More Miles Long, Out of State Top 25 Priority Hotspots, 2007-2016.

District Rank	State Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
1	2	US 395A	US 395 Granite Peak	WA 33.5	WA 38.75	5.70	64	11.22
2	5	SR 431	SR 431 Mount Rose Foothills	WA 16.9	WA 22.4	5.53	43	7.78
3	6	I-580/US 395A	I-580 & US 395A South Washoe Lake	I-580 WA 2.78	I-580 WA 7.96	6.18	46	11.22
				US 395 WA 1.2	US 395 WA 2.2			
		Includes all 3 roads on the SW end of Lake Washoe: I-580, US 395A, & SR 877						
4	8	I-80	I-80 Stateline to Reno	SR 647 WA 8.5	SR 647 WA 9.0	12.29	89	7.24
				I-580 WA 0.5	I-580 WA 8.5			
				SR 425 WA 2.8	SR 425 WA 6.8			
		West of Reno to California State Line and, includes I-80 Loop = SR 425 in Verdi						
5	10	US 50	US 50 West Fallon	CH 17.5	CH 20	2.50	17	6.80
6	19	US 50	US 50 Fallon-Ragtown	US 50 CH 12	US 50 CH 15	4.11	24	5.84
				SR 117 CH 0	SR 117 CH 1			
		Intersection of US 50 and SR 117						
7	20	US 50	US 50 Spooner Summit	US 50 DO 11	US 50 DO 14.5	9.64	55	5.71
				US 50 CC 0	US 50 CC 5			

District Rank	State Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
				SR 28 DO 0	SR 28 DO 1			
		US 50 in the Mountains west of Carson City, to the intersection with SR 28 and toward Lake Tahoe						
8	24	US 95A	US 95A Stillwater National Wildlife Refuge	LY 34.6	37.3	2.51	14	5.59

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

The Nevada top 25 wildlife-vehicle collision crash hotspots equal to or greater than two miles in length that ocurred in NDOT District III are presented in Figure 32.



District Rank	Rank	Road	Length (miles)	Number of Incidents	Normalized Occr.	District	County
1	1	I 80	6.072	81	13.340	District III	Elko
2	3	I 80	2.528	21	8.308	District III	Elko
3	4	SR 227	4.015	32	7.970	District III	Elko
4	7	SR 227	3.516	26	7.396	District III	Elko
5	9	US 6	4.025	28	6.957	District III	White Pine
6	11	US 6	3.003	20	6.661	District III	White Pine
7	12	US 95	3.001	19	6.331	District III	Humboldt
8	13	US 93	6.009	37	6.158	District III	Elko
9	16	I 80	2.542	15	5.900	District III	Elko
10	21	US 50	3.533	20	5.661	District III	White Pine
11	23	US 93	2.503	14	5.594	District III	Elko

*Top NDOT District Wildlife-Vehicle Collision Crash Hotspots greater than 2 linear miles

Figure 32. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada That Occurred in NDOT District III 2007-2016, Two or More Miles Long, Based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros.

Each of the Nevada top 25 Wildlife-Vehicle Collision crash hotspots greater than or equal to two miles in length that occurred in District III are presented in Table 27.

Table 27. Nevada Department of Transportation District III Top Hotspots of Wildlife-Vehicle Collision Crashes Two or More Miles Long, Out of State Top 25 Priority Hotspots, 2007-2016.

District Rank	State Rank	Road	Potential Name	~ Mile Marker Start*	~ Mile Marker Finish*	Length (miles)	Number of Crashes	Crashes/ Mile/10 Years
1	1	I 80	I-80 Pequop Summit	EL 93.8	EL 99.8	6.07	81	13.34
2	3	I 80	I-80 Silver Zone	EL 112.5	EL 115	2.52	21	8.31
3	4	SR 227	SR 227 Elko Hills	EL 1.9	EL 5.9	4.02	32	7.97
4	7	SR 227	SR 227 Spring Creek	EL 12.6	EL 16.1	3.56	26	7.40
5	9	US 6	US 6 Western Eagan Range Foothills	WP 28.5	WP 32.5	4.03	28	6.96
6	11	US 6	US 6 Steptoe Valley Wildlife Management Area	WP 42.5	WP 45.5	3.00	20	6.66
7	12	US 95	US 95 Quinn River Valley	HU 38.5	HU 41.5	3.00	19	6.33
8	13	US 93	US 93 HD Summit	EL 90	EL96	6.01	37	6.16
9	16	I 80	I-80 Humboldt River	EL 14.7	EL 17.2	2.54	15	5.90
10	21	US 50	US 50 Eagan Range Robinson Summit	WP 46.7	WP50.2	3.53	20	5.66
11	23	US 93	US 93 Ten Mile Summit	EL 82.5	EL 85	2.50	14	5.59

** Mile Markers Name Include Abbreviation for County Where Mile Markers Occur. CC=Carson City, CH=Churchill, CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, LN=Lincoln, LY=Lyon, ST=Storey, WA=Washoe, and WP= White Pine.*

Wildlife Hotspot Map Laid Over Wildlife Habitat Maps

The top 25 wildlife-vehicle collision crash hotspots were laid over mule deer and elk habitat maps developed by NDOW, Figure 33.

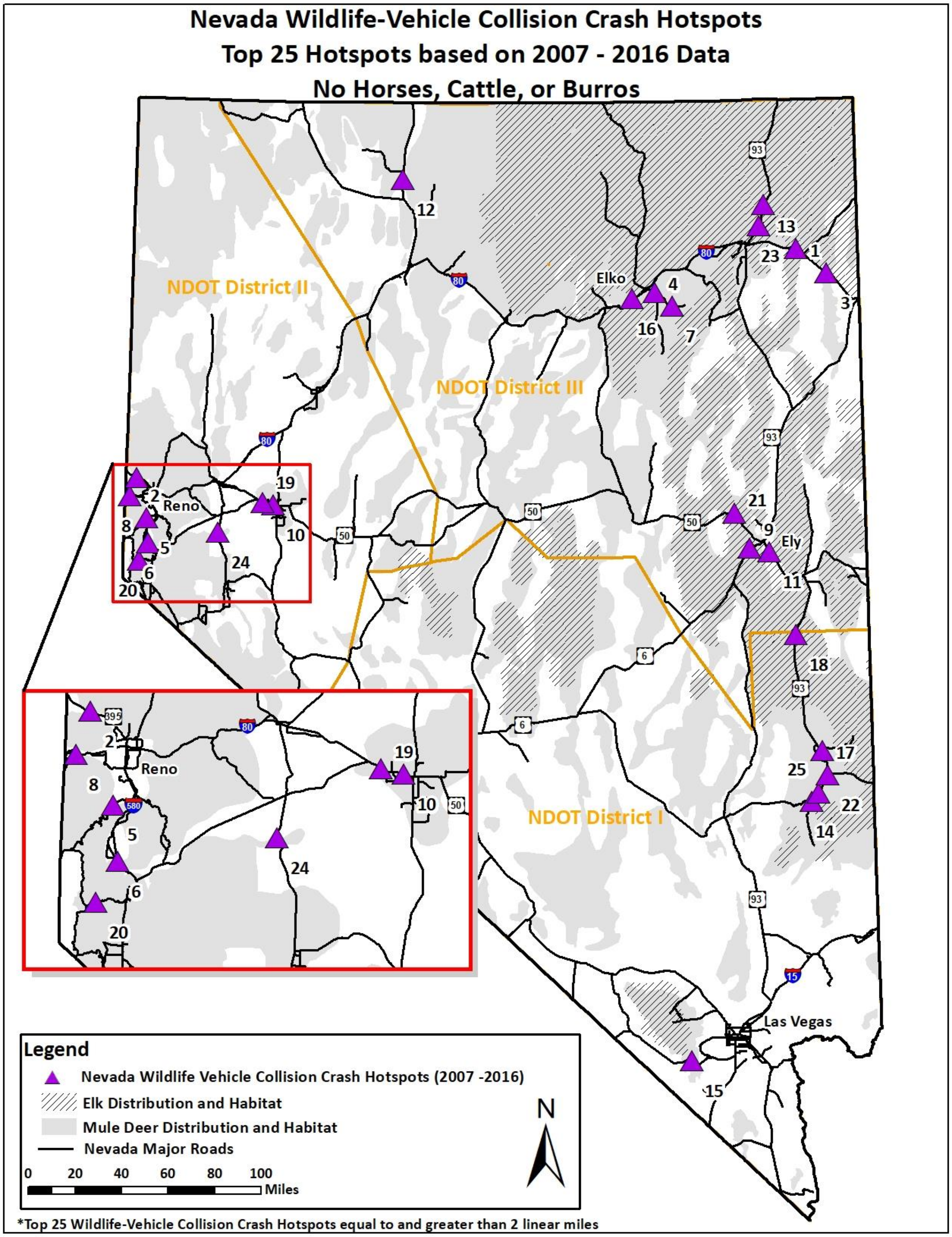


Figure 33. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada 2007-2016, based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros. Hotspots Laid Over Mule Deer and Elk Habitat Maps from Nevada Department of Wildlife.

Methods and Results from Modeling Priority Areas Based on Safety and Ecological Information

In these mapping models, the final prioritization map combined crash data with other georeferenced data to build maps that better inform priority animal-vehicle CONFLICT hotspots, rather than past animal-vehicle CRASH hotspots, as was done in the priority mapping above. When the additional data are used, it helps to predict areas of potential conflict with animals where there are little to no crash data, as well as bring together multiple pieces of information to create a more informative map that includes many factors.

Methods Used to Model Safety and Ecological Data to Determine Priority Hotspots

In this modeling step a safety map layer and an ecological map layer were created and scored, both with a total of 50 potential points, and then combined for a map with a potential high score of 100 points for each half mile segment of NDOT roads. The layers of NDOT roads, mile markers, average annual daily traffic (AADT), crash, and carcass data were combined to create the safety layer map (see Table 28). The ecological map was created by combining wildlife habitat maps plus horse and cattle hotspot maps (Table 28). The total of 100 points were based on the presence of the attribute in each GIS layer, such as the presence of mule deer habitat, or the number of animal-vehicle collision crashes. The values for scoring were based on the data from this study, literature, and input from the research panel as to what factors were most important. For example, panel members thought half-mile segments where a fatal crash occurred with an animal should have a rating of seven, versus the five points originally proposed. Previous hotspot modeling steps informed the thresholds for classes of crash data so crash top 25 hotspots were the base of the thresholds for the highest value score for crashes. A one-page score card is presented in Table 29 for ease of viewing.

Results of Safety and Ecological Mapping and Prioritization

The safety map is displayed in Figure 34, below, with the highest scoring half-mile segments displayed in red and colors progressing away from red to orange and then yellow as the safety scores of the half mile segments become lower.

Table 28. Score Card for GIS Values of Safety and Ecological Data for Each One-Half Mile Segment of Road, with Explanations.

Information-GIS Layer to Evaluate a Half-Mile Segment of Road for Scoring	Range of Values	Classes of Points	Max Points	Notes on How Rankings Were Decided
GIS Safety Information				
Number of Animal Crashes/mile/year	> 0.65	20	20	Per Mile per Year. This includes all top 25 animal crash hotspots
	> 0.00-0.65	10		For segments with small amounts of hotspots up to just less than the number 25 hotspot.
	0	0		
Number Human Fatalities	≥ 1	7	7	Number of fatal crashes with animals involved
	0	0		Value was derived from panel input
Number of Human Injury	> 1	5	5	Number of injury crashes with animals involved
	1	3		Value was derived from panel input
	0	0		
Number of Carcasses /mile/year	> 1		3	Per Mile per Year. From top 25 priority hotspots' carcass numbers. Higher ranking priority hotspots have value > 1.
	0.10-0.99	2		Some of the top 25 hotspots have these values
	0	0		
Average Annual Daily Traffic	>9,999	10	10	Higher AADT = less permeable for animals, and more highly scored for the need for wildlife crossings. ~10,000 AADT, low chance of success of animals crossing, traffic is a barrier. See Charry & Jones 2009 as reference.
	2,001- 9,9999	5		
	< 2,000	0		Traffic low enough that there is high chance of staying alive upon crossing, for ungulates. Still could be problems, but not as much as higher levels.
Percentage AVC	>10.6	5	5	Percentage of crashes involving animals. Based on Task 1 data analyses, & counties with highest proportions of AVC crashes. 10 out of 17 counties = proportion, with numbers greater than 10.6%
	2.4 - 10.6	3		From state average to the 4 counties that have AVC % from 3.0 to 10.6
	<2.4	0		State average. If it is less than state average, AVC are not a major concern
Total for Safety map			50	

Information-GIS Layer to Evaluate a Half-Mile Segment of Road for Scoring	**Range of Values**	**Classes of Points**	**Max Points**	**Notes on How Rankings Were Decided**
GIS Wildlife-Livestock Information				
Mule deer habitat	Includes Habitat Map	5	5	Binary values, based on binary map. Either yes or no mule deer habitat.
	No Habitat	0		
Mule deer movement corridors	Includes Corridor Map	5	5	Binary values, based on binary map.
	No Corridors	0		
Horse crash data – number of horse-vehicle crashes	> 0.11	10	10	No GIS data on habitat, so we evaluate horses based on crash data. Panel members asked for high rank for horses due to the dangers of vehicle collisions with them. This equates to anything greater than 1 crash /mile/year and includes all the hotspots. The lowest value is 0.199 per mile per year
	0-0.10	0		This means if there is one crash per one mile in 10 years, it equates to 0.1 crash per mile per year, not enough for a hotspot.
Cows number of cattle-vehicle crashes	> 0.11	10	10	No GIS data on habitat, so we evaluate cows based on crash data. Panel members asked for high rank for cows. This equates to anything greater than 1 crash /mile/year and includes all the hotspots. The lowest value is 0.199 per mile per year
	0-0.10	0		This means if there is one crash per one mile in 10 years, it equates to 0.1 crash per mile per year, not enough for a hotspot.
Elk habitat	Includes Habitat Map	5	5	Binary values, based on binary map.
	No Habitat	0		
Pronghorn habitat	Includes Habitat Map	5	5	Binary values, based on binary map.
	No Habitat	0		
Bighorn sheep habitat	Includes Habitat Map	3	3	Binary values, based on binary map.
	No Habitat	0		

Information-GIS Layer to Evaluate a Half-Mile Segment of Road for Scoring	Range of Values	Classes of Points	Max Points	Notes on How Rankings Were Decided
Bighorn movement corridors	Includes Corridor Map	5	5	This helps account for importance of movement areas for bighorn and the fact individual animals killed more greatly affect the local populations than do mule deer losses. Binary values, based on binary map.
	No Corridors	0		
Black bear habitat	Includes Habitat Map	2		Binary values, based on binary map.
	No Habitat	0		
Total Points for Ecological Map		50		
Total points		100	100	

Table 29. GIS Score Card for Safety-Ecological Wildlife-Vehicle Conflict Priority Hotspots. One Page.

Information-GIS Layer to Evaluate a Half-Mile Segment of Road for Scoring	Range of Values	Classes of Points	Max Points
GIS Safety Information			
Number of Animal Crashes /mile/year	> 0.65	20	20
	> 0.00-0.65	10	
	0	0	
Number Human Fatalities	≥ 1	7	7
	0	0	
Number of Human Injury Crashes	> 1	5	5
	1	3	
	0	0	
Number of Carcasses / mile/year	> 1	3	3
	0.10-0.99	2	
	0	0	
Average Annual Daily Traffic	>9,999	10	10
	2,001- 9,9999	5	
	< 2,000	0	
Percentage AVC	>10.6	5	5
	2.4 - 10.6	3	
	<2.4	0	
Total for Safety map			50
GIS Wildlife-Livestock Information			
Mule deer habitat	Includes Habitat Map	5	5
	No Mule Deer	0	
Mule deer movement corridors	Includes Corridor Map	5	5
	No Mule Deer Corridors	0	
No. of horse-vehicle crashes/mile/year	> 0.11	10	10
	0-0.10	0	
No. of cattle-vehicle crashes/mile/year	> 0.11	10	10
	0-0.10	0	
Elk habitat	Includes Habitat Map	5	5
	No Elk Habitat	0	
Pronghorn habitat	Includes Habitat Map	5	5
	No Pronghorn Habitat	0	
Bighorn sheep habitat	Includes Habitat Map	3	3
	No Bighorn Habitat	0	
Bighorn movement corridors	Includes Corridor Map	5	5
	No Bighorn Corridors	0	
Black bear habitat	Includes Habitat Map	2	
	No Bear Habitat	0	
Total Points for Ecological Map		50	
Total points		100	100

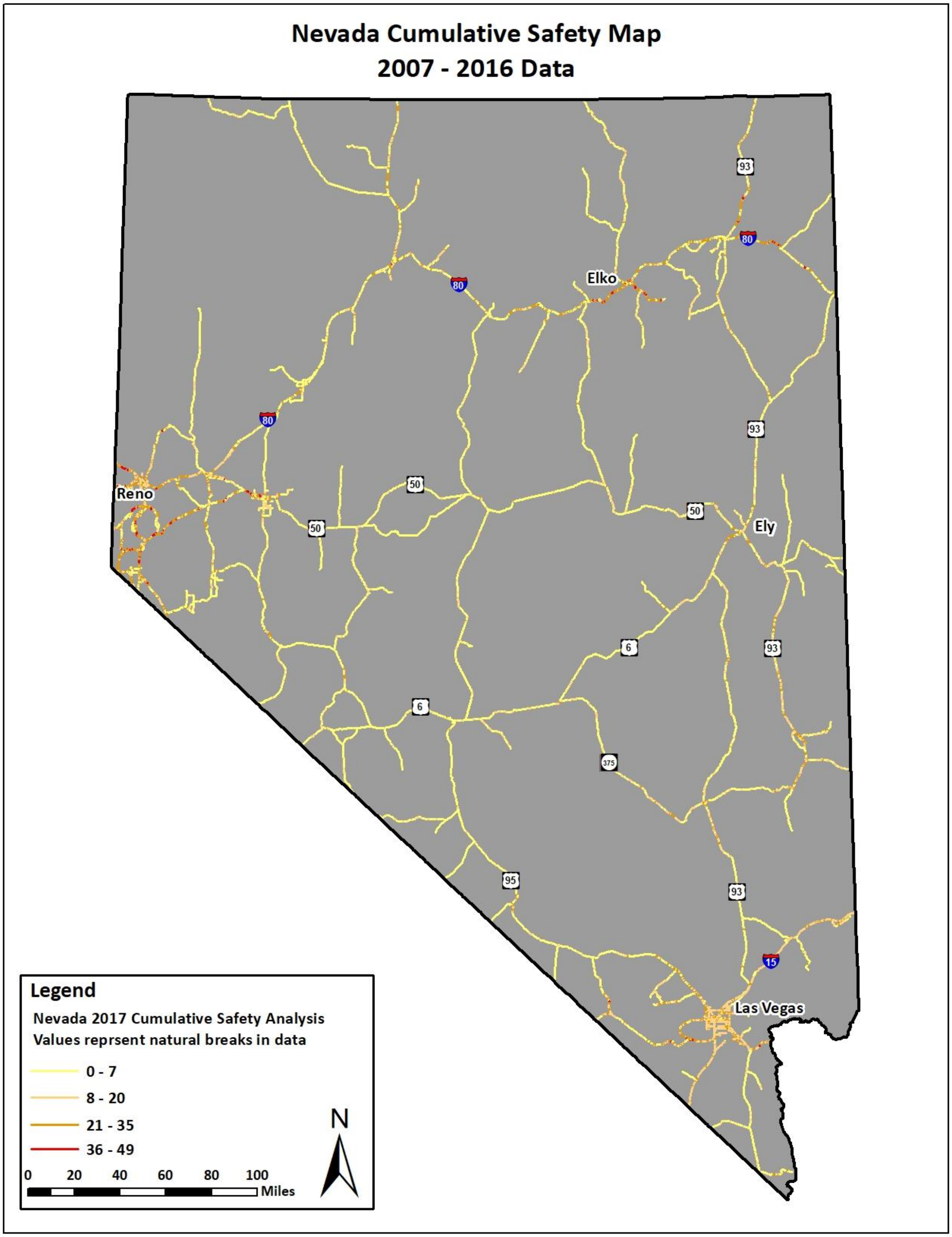


Figure 34. Safety Map for Input into Safety and Ecological Prioritization for Animal-Vehicle Conflict Hotspots.

The two most highly ranked half mile segments of road in the safety map were those where people died in crashes with animals, where there were animal-related crashes with human injuries, there were some carcass data, the AADT was at least 10,000, and animal-vehicle collision crashes were at least 23 percent of all reported crashes, see Figure 35. There were two number 1 hotspots, both with a score of 49 out of 50. The numbers 1,2, and 5 hotspots for safety in the state are delineated in the figure. NDOT District II in the Reno area had the heaviest concentration of high value red segments of road in the safety map out of all districts.

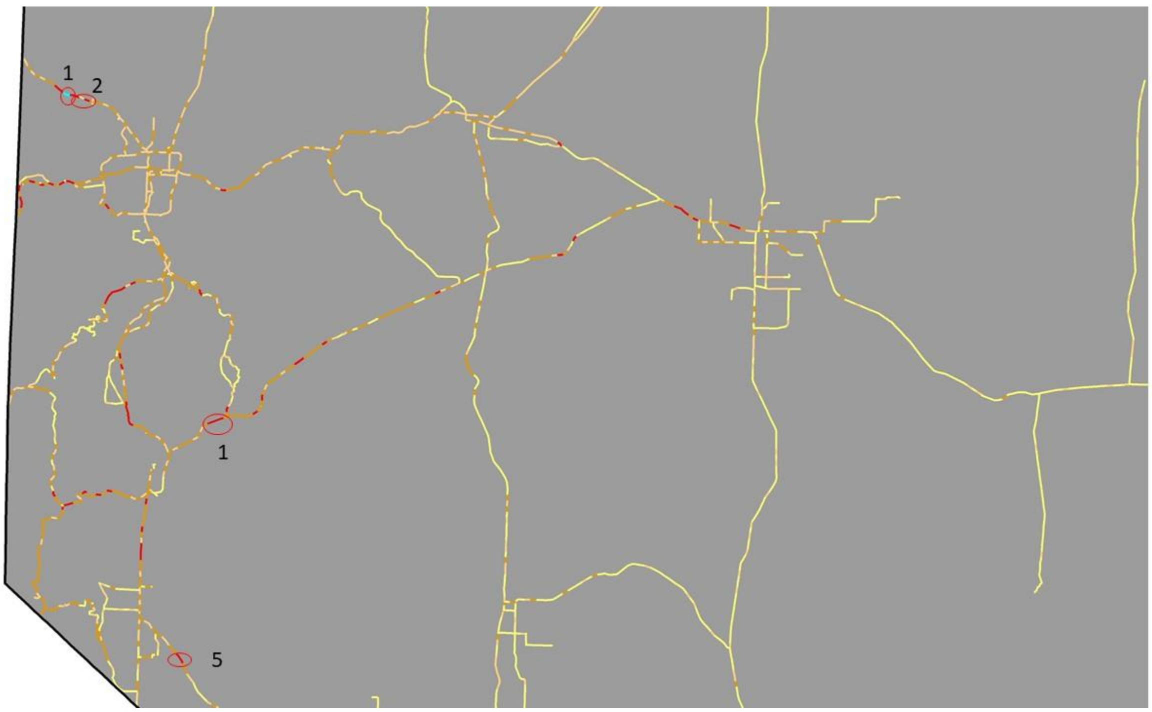


Figure 35. Nevada DOT District II Reno-Carson City Area top Safety Half-Mile Segments, with segments in the Top 100 Rankings in Red, Second Tier Ranked Segments in Orange, and Yellow for Segments with Lower Safety Scores. Highest Scoring Segments Are Circled and Labeled.

The Ecological map was calculated based on the wildlife habitat and corridors (Figure 36), and horse and cattle crash values. It did not produce as many ‘hot’ areas of red as the safety map, Figure 37. More wildlife habitat was overall in the NDOT District III area of the state. Thus, this district’s roads have the ‘hottest’ colors of shades of orange and red segments. Values of half-mile segments ranged from zero to 40.

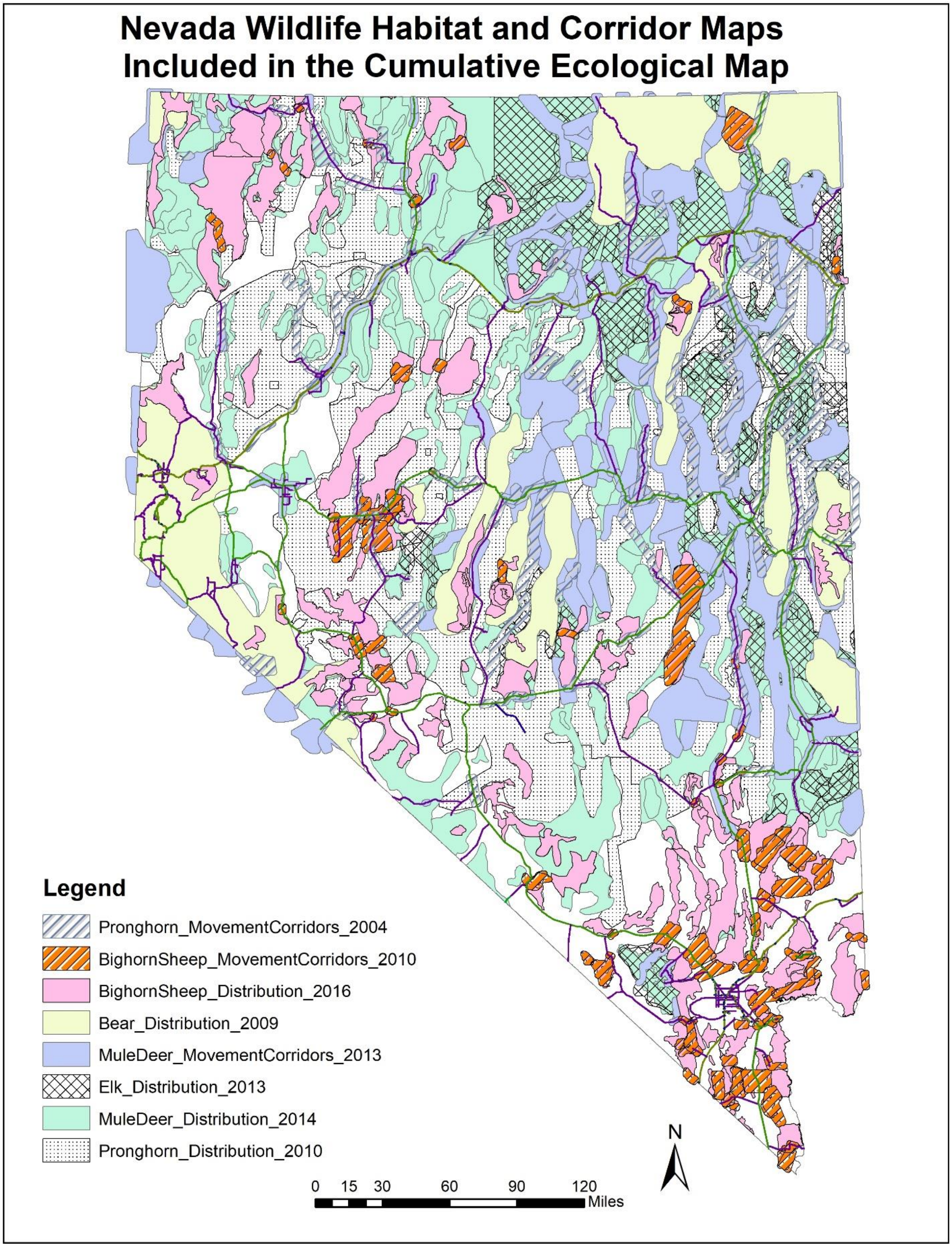


Figure 36. Wildlife Habitat and Corridor Maps Included in the Cumulative Ecological Map.

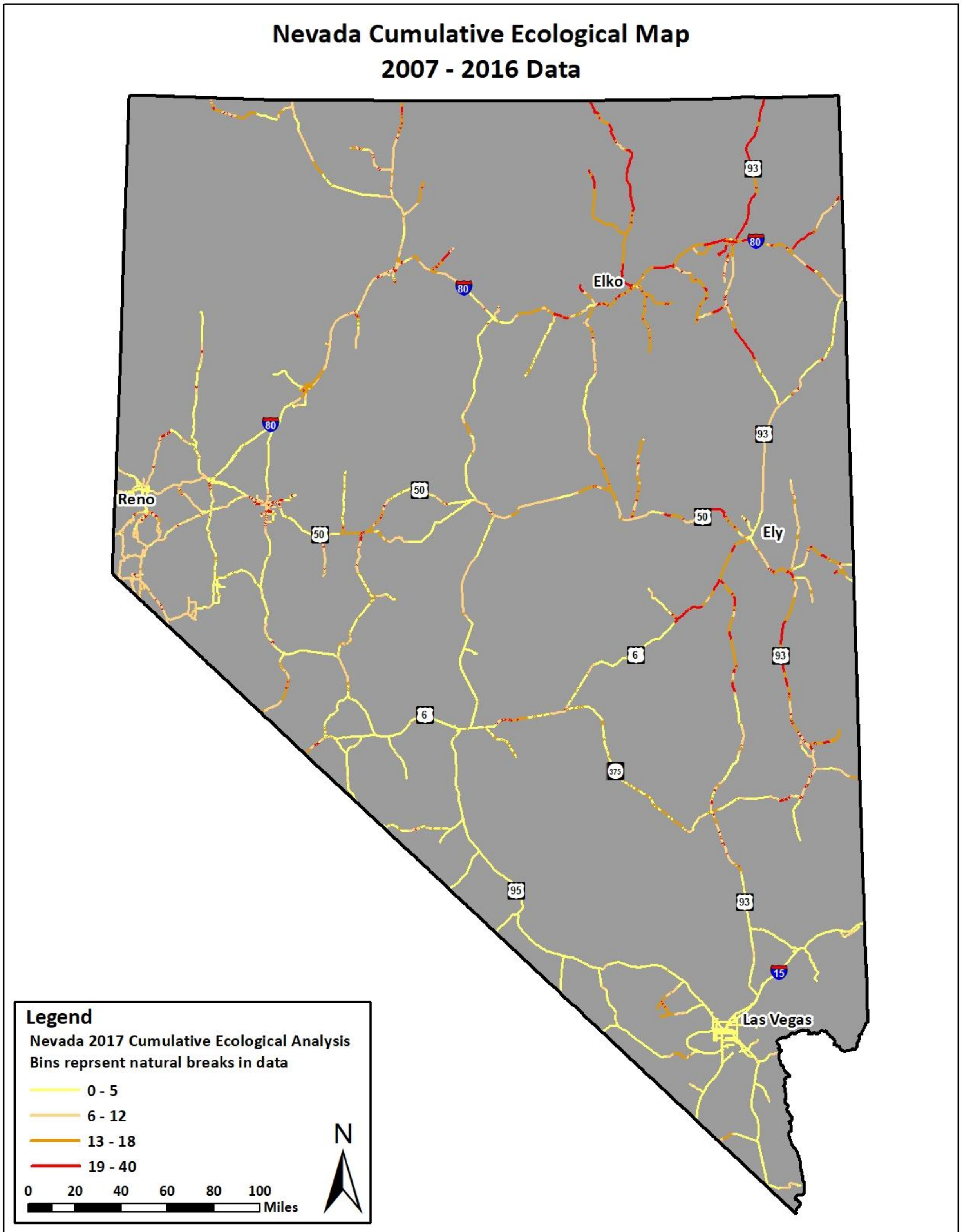


Figure 37. Wildlife-Ecological Map for Inclusion in Prioritization of Top Animal-Vehicle Conflict Hotspots.

The top ecological road segment had an Ecological Cumulative score of 40 out of a possible 50 points. This segment was on State Road 322, East of Pioche, District I. It had mule deer habitat, mule deer corridors, elk habitat, pronghorn habitat, and horse and cattle crashes recorded in the half mile segment. The second highest ecological score for a road segment (37) was on US 93, north of HD Summit wildlife mitigation, at Table Top Mountain. NDOT District III had a majority of the red or most highly scored segments, see Figure 38, below.

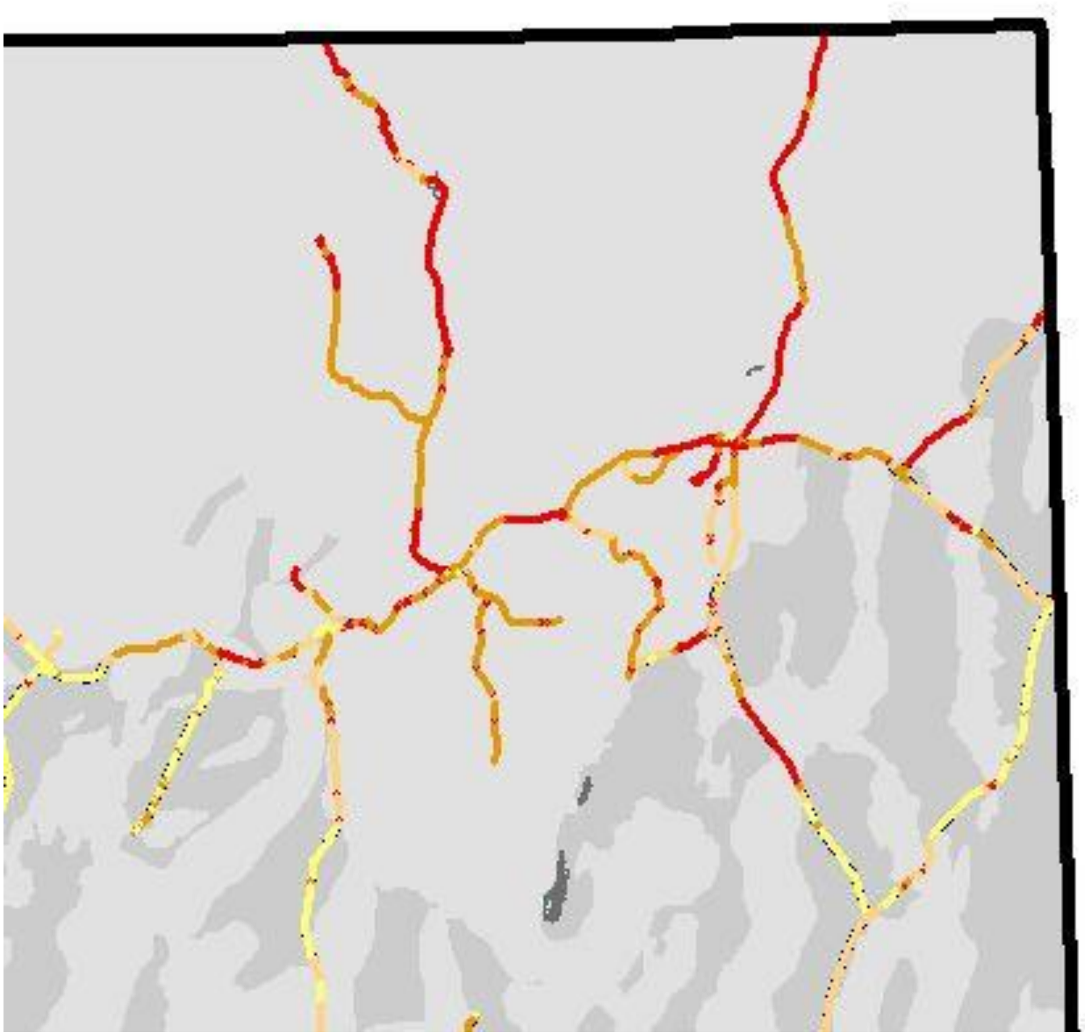


Figure 38. Top Cumulative Ecological One-Half Mile Segments in Northeast Corner of Nevada in NDOT District III. Segments Scoring 19 to 40 in Red, and Lower Scores Represented in Shades of Orange and Yellow. Mule Deer Habitat Map Laid in the Background.

The Safety Map and Ecological Map were combined to form the Animal-Vehicle Conflict Cumulative Safety and Ecological Priority Areas Map, Figure 39. The ranking of each half mile segment was based on the number of cumulative points that segment received from each map.

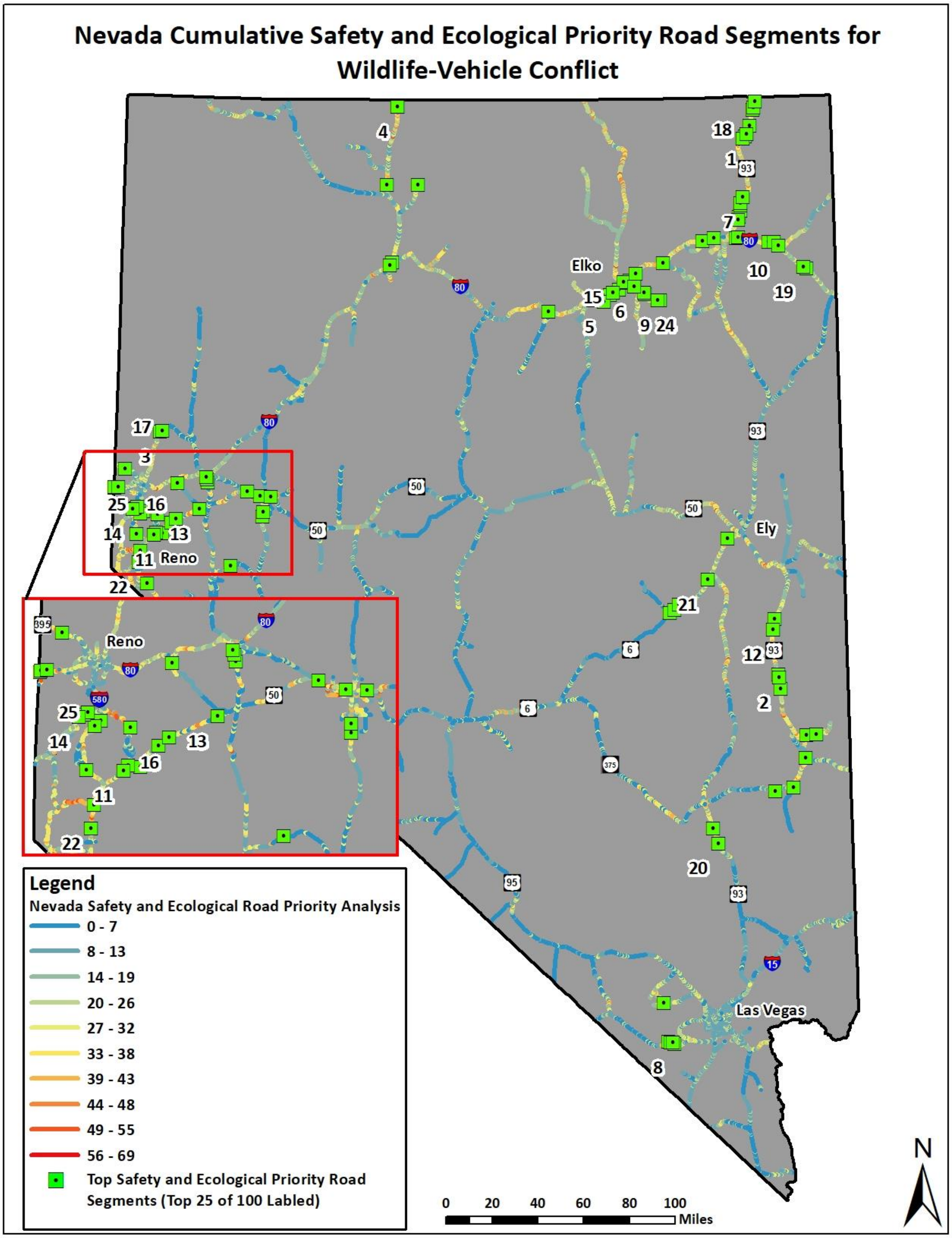


Figure 39. Priority Road Segments for Wildlife-Vehicle Conflict Based on Ecological and Safety Maps Combined. Top 25 Listed, Top 100 Road Segments Presented in Green Boxes. Modeled on Data from 2007-2016.

Several top 100 half-mile segments were adjacent to one another. Although each segment was an independent unit of analysis for this and the previous GIS modeling, there was still some spatial auto-correlation, meaning the half-mile segments were part of a larger hotspot area. Seventeen of the top 25 priority half-mile segments were adjacent to another priority half-mile segment. To account for this, the researchers used the dissolve feature in ArcGIS and assigned the new larger segment the maximum value of the two smaller segments. This means that the entire segment was evaluated as a high area of concern, whereas, if this was not done, the results might have two segments that are adjacent to one another, both falling in the top 100, but ranked very differently. This method removed the autocorrelation issue for the two smaller segments by joining them spatially.

Getis-Ord hotspot modeling was not performed on this map because each half mile segment had but one value, the cumulative points for safety and ecological data. Getis-Ord needs several to many incidences in a segment to perform its type of cluster analysis. With just one value per half-mile segment, the segments were color coded based on the cumulative values. Color categories were selected by the Bin function in ArcGIS.

The top 25 priority animal-vehicle conflict segments are presented in Table 30, with road numbers, potential names, and score values.

Table 30. Top 25 Hotspots of Animal-Vehicle Conflict Based on Safety and Ecological Data.

Rank	Road	Potential Name = Road, Location, and Mile Marker	Mile Markers*	Length Miles	Safety Value	Ecological Value	Total Points	If in a Getis-Ord Animal-Crash Hotspot, Rank?	District
1	US 93	US 93 Table Top Mountain	US 93 EL 123-126	3.0	32	37	69	No	III
2	US 93	US 93 Fairview Range	US 93 LN 147-148.4	1.4	32	37	67	No	I
3	SR 445	SR 445 Mullen Creek	WA 24.5 - 25	0.5	30	35	65	No	II
4	US 95	US 95 Quinn River Valley	US 95 HU 69 – 71.5	2.5	30	34	64	No	III
5	I-80	I-80 Moleen-Humboldt River	I-80 EL 8 - 12	4.0	48	15	63	No	III
6	SR 227	SR 227 Spring Creek Area	SR 227 EL 2 -6	4.0	38	25	63	No	III
7	US 93	US 93 North of Wells	US 93 EL 94 - 95	1.0	43	20	63	No	III
8	SR 160	SR 160 Mountain Springs	CL 19.7 – 23.3	3.6	43	18	61	16	I
9	SR 227	SR 227 Pleasant Valley	SR 227 EL 17.5 - 18	0.5	36	25	61	0	III
10	I-80	I-80 Pequop Summit	I-80 IR 94 - 100	6.0	36	25	61	2	III
11	US 50	US 50 - SR 341 Intersection	US 50 LY 0 – 5.1 SR 341 LY 0 – 1.1	6.2	49	12	61	8	II
12	US 93	US 93 LI - WP County Line	US 93 LN 169 - 171	2.0	30	30	60	0	I
13	US 50	US 50 Horse Fence End	US 50 LY 24 - 25	1	40	20	60	7	II
14	SR 431	Mt. Rose Highway	WA 18 – 20.3	2.3	40	20	60	4	II
15	I-80	I-80 West Elko	EL 15 - 17	2.0	40	20	60	0	III
16	US 50	US 50 Dayton	US 50 LY 13 – 14.5	1.5	37	22	59	8	II
17	SR 445	SR 445 Mullen Pass	WA 25.5 - 26	0.5	37	22	59	0	II
18	US 93	US 93 Table Top Mountain S	I-80 EL 121.5 - 123	1.5	32	27	59	0	III
19	I-80	I-80 Silver Zone	I-80 IR 113.5 - 117	3.5	39	20	59	14	III
20	US 93	US 93 Pahranagat Valley	LN 31.7 – 32.2	0.5	28	30	58	0	I
21	US 6	US 6 Currant	US 6 WP 9.7 -10.2	0.5	28	30	58	0	I
22	US 395	US 395 Carson River	DO 28.6 - 29.1	0.5	41	17	58	0	II
23	I-80	I-80 Carlin	I-80 EL 4.5 - 7	2.5	38	20	58	0	III
24	SR 227	SR 227 Lamoille	SR 227 EL 16.5 - 17	0.5	33	25	58	0	III
25	SR 431	Mt. Rose - Whites Creek	WA 20.8 – 21.3	5.0	40	17	57	6	II

** Mile Markers Name Abbreviation for County of Occurrence: CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, IR = Iron, LN=Lincoln, LY=Lyon, WA=Washoe, and WP= White Pine.*

Discussion

The data the researchers analyzed and mapped were all available to NDOT personnel but have never been analyzed in such detail. The mapping and statistical hotspot analysis allowed quantifiable methods to show exact locations of crashes with various types of animals and identify the areas of greatest concern based on total numbers of crashes over one-half mile road segments. The analyses revealed four overall important points: wildlife-vehicle collision crash analyses are not only about mule deer and other wildlife, but also about horses and cattle; it takes detailed analyses to find the problem areas and what animals were involved; creating a priority map based on multiple factors helps reveal true animal-vehicle conflict; and the hotspot modeling is heavily technical and needs to be conducted repeatedly with different parameters and analyses to find the best, most accurate fit for the data and on the ground realities.

Species of Animals

The mule deer is the animal most involved in vehicle collisions. Past, current, and future wildlife mitigation across Nevada will be targeted predominantly toward this species. The mapping allowed visualization of the places deer were involved in collisions, and the hotspots. The remaining recorded crashes with wild animals were only 37 percent of the number of deer-vehicle reported crashes. Thus, this mapping and hotspot activity was best suited for mitigation solutions for mule deer. However, coyote/dog, elk, pronghorn, bear, and bighorn sheep are all involved in collisions, and Table 17 can help to elucidate how each of these species is involved in the top animal-vehicle collision crash hotspots. Nevada requires identification of animals involved in crashes, which provides very valuable information on how to mitigate these problem areas. Future actions should be based on the species involved in crashes and mitigation solutions known to work for those species, and not only mule deer.

The data presentations in the above maps reveal that each NDOT district has its own distinct species and hotspot problem areas. The problem of horses on the road is most acute in District II. Thirteen of the top 25 horse hotspots in the state were clustered within 30 miles of Reno within District II. Horses are also a problem for NDOT District I. The horse crash hotspots in District I are all on US 93, in Lincoln County. Horses are of less concern for NDOT District III.

Cattle are a problem as well. NDOT Districts I and II have the majority of the cattle hotspots. In general, the cattle hotspots are concentrated on the west side and southern half of the state. State Road 375, the Extraterrestrial Highway, in the Tikaboo Valley appears to have the worst cattle-vehicle collision problem for all roads in the state. These maps can help NDOT personnel pinpoint problem areas and go to those places to trouble-shoot these open range areas.

Bighorn sheep typically do not exist in large numbers as mule deer and elk do in any western state. Their numbers can be in smaller herds, which are much more heavily decimated by deaths by vehicle collisions than mule deer or elk herds. As a result, the analyses did not identify bighorn sheep hotspots, because the general crash and carcass numbers were not on par with mule deer and even elk. This species is especially vulnerable to becoming overlooked in any type of prioritization due to its low numbers. Thus, through all this prioritization work, it is unfortunate that bighorn sheep populations subject to death of members by vehicle collisions were not identified. Therefore, on the ground knowledge by NDOT, NDOW, and members of the public is critical to finding solutions for reducing bighorn sheep deaths from vehicle collisions. This example is also an important reminder that not all animal numbers, and non-georeferenced knowledge were included in these prioritizations, and other methods of establishing priorities should be embraced.

Detailed Analyses Revelations

The data analyses and mapping allowed comparisons among the NDOT districts and species involved in crashes. NDOT District II has far more of the overall hotspots mapped than any other NDOT district (Table 31). District I have a greater proportion of their hotspot problems due to livestock than other districts. District III is home to predominantly wildlife-vehicle collision crashes. The data analyses revealed specific problem hotspots and types of animal-crash areas that each NDOT district will need to address.

Table 31. Each Nevada Department of Transportation Districts' Top Hotspots from Different Hotspot Modeling Scenarios: All Animals, Wildlife, Horses, and Cattle, and Safety-Ecological.

	NDOT District		
Type of Hotspots	**I**	**II**	**III**
Animal	5	11	9
Wildlife	6	12	11
Horse	11	10	0
Cattle	9	12	4
Animal-Vehicle Conflict Safety-Ecological Hotspot	5	8	12
Totals per District	36	53	36

Looking at the attribute tables of the hotspot shape files and investigating in greater detail each hotspot is a necessity for determining what was happening over space and time. The researchers examined all crashes at each hotspot of the animal-vehicle collision crashes two miles and greater in length to find the species involved. This is important for all next steps in addressing each of the hotspots. There were hotspots dominated by mule deer, horses, elk, cattle, and even burros. The measures to reduce these collisions are very different for all these species.

Fatal left road and rollover crashes were mapped and laid over wildlife habitat and paired with the animal-vehicle collision crash hotspots. There is a concentration of these types of fatal crashes in Elko County, which covers the northeast corner of Nevada. There were four new wildlife crossing underpass structures and five wildlife overpass structures on US 93 and I-80 completed over the 10-year period of the crash data. In future analyses, it would help the theory that animals were involved in fatal crashes and not accounted for if the areas with the recently completed wildlife mitigation were analyzed for these types of fatal crashes pre and post wildlife crossing structures and fences and these fatal crashes decreased.

It is also important to note that one-third of all fatal crashes with animals occurred with motorcycles. Motorcyclists were just 10.7 percent of all crash fatalities in the 2006-2015 crash data. These motorists are the type most at risk for severe injury and death from animal-crashes.

GIS Modeling

The hotspot modeling was an iterative process over one year to find the most suitable methods to extract animal data out of the crash database, GIS methods, scales of inquiry, and statistical confidence intervals. A GIS expert can know how the ArcGIS spatial modeling process works, and a NDOT safety analyst can understand the way crash and carcass data are collected and extracted, but it is important that the NDOT and NDOW experts who understand the landscape, animal problems, human development, and NDOT processes are also involved in the mapping process. As the hotspot mapping processes was stepped through, NDOT and NDOW personnel weighed in as to why and how hotspots were where they were and how they were prioritized correctly or incorrectly. An example of this is the choice of confidence intervals for Getis-Ord.

Getis-Ord Gi* spatial modeling tool in ArcGIS outputs hotspots with levels of confidence that the algorithms in the modeling created the most appropriate and accurate hotspots. The spatial clustering of the crash locations is analyzed based on the next two neighboring cells (a one-mile search distance) from the one-half mile cell under consideration (See Appendix E for greater details). For a half-mile cell of road to rank as a statistically significant hotspot, the cell will be surrounded by other high value half-mile cells. When a 99 percent confidence interval is used, it typically slightly truncates the length of the 95 percent confidence interval hotspot lengths. This is because the ends of the hotspots are near areas without many crashes, and under the 99 percent confidence interval analyses, the model is less certain that these areas are truly hotspots if the outside cells have less crashes than the inside cells. As a result, 99 and 95 percent confidence interval analyses output different hotspot locations. The researchers began with 99 percent confidence intervals and top 20 hotspots. When areas with crashes with animals appeared to be significant but did not show up in the top 20 hotspots, panel members, including NDOW's Cody McKee, asked that the analyses be re-run to find ways to account for these hotspots. The researchers then ran the analysis with 95 percent confidence intervals and took the top 25 hotspots to create a more inclusive priority list. This analysis became the master method for top priority areas of animal, wildlife, horse, and cattle vehicle collisions. As the researchers investigated these hotspots, they found smaller sections under two miles were being ranked against longer sections and at times ranking higher than longer sections of hotspots, which seemed a bit counter-intuitive. The researchers then created a hotspot map and table of the smaller sections of animal-vehicle collision crashes. In future prioritization hotspot mapping, these considerations should be taken into account. NDOT and NDOW personnel should be involved in quality assurance and peer review of these analyses.

Creating a Priority Map Based on Multiple Factors Helped Reveal True Animal-Vehicle Conflict

When crash data went from 100 percent of the input into the hotspot analyses to 32 percent of the Safety and Ecological animal-vehicle conflict priorities, other factors such as mule deer habitat became contributors to the top priority areas. This allowed for a more complete overview of the potential for animal-vehicle conflict, rather than animal-vehicle reported crashes. It also allowed for ranking small, one-half mile segments that could be most critical to animal-vehicle conflict, rather than using an ArcGIS clustering model to aggregate half mile segments into longer hotspots. While only five of the top 25 half mile wildlife-vehicle conflict segments were within larger animal-vehicle collision reported crash hotspots, this analysis revealed other areas of concern for NDOT. When the top 100 priority half-mile segment animal-vehicle conflict hotspots were compared with the top 25 crash hotspots, half of them were within these prior hotspots. For Nevada to truly address animal-vehicle conflict rather than past crash locations, this map is critical to this overall approach. It is also important to consider these ecological and safety factors in tandem when addressing future mitigation for wildlife and safety.

The Ecological and Safety Map of animal-vehicle conflict hotspots may be the most accurate map for predicting where wildlife and livestock mitigation may need to be placed. Crashes do predict the past and to some extent the future, but they fail at predicting where unreported crashes occur, future traffic volumes, new roads, and places where animals cannot get across roads. Neumann et al. (2012) modeled spatial temporal patterns of locations where collared moose were predicted to have crossed the road, judging from data point locations, and locations of moose-vehicle collisions. Their conclusions were that efforts to reduce wildlife-vehicle collisions should combine locational data of actual animals on the landscape, and collision data. Each data set alone did not fully predict areas where animals crossed roads and needed connectivity across the landscape. Their findings also suggested that higher collision risk with moose was largely due to low light and poor road surface conditions rather than to more animal road-crossings. They recommend efforts be focused on driver attitudes and road conditions rather than animal movement data. The study was conducted in Sweden, where road and forest conditions are very different than Nevada. The results and recommendations however draw attention to the idea that animal presence alone is not the determining factor in risk of collisions with animals, and factors such as surrounding wild area, road conditions, types of vehicles driven (18-wheeler trucks versus passenger cars) and driver attitudes come into play.

Recommendations

Crash and Carcass Data Are Not the End All

Through discussions with members of the NDOT-NDOW panel it was learned that the southwestern area of the state has far more bighorn sheep and burro collisions than are represented in the databases. This concern brings up a valid point, that not all collisions with animals and not all carcasses are reported. As stated in the report, past studies have found crashes record anywhere from 10 to 20 percent of the number of carcasses collected (Olson 2013, Donaldson and Lafon 2009). Therefore, actions for prioritizing mitigation measures for animals across the state should not be based solely on crash and carcass data. The Framework in Chapter 6 where other information is used in to prioritize should also be taken into consideration.

NDOT and NDOW Personnel Will Need to Be Involved in the Next Hotspot Modeling Process

NDOT and NDOW personnel on the panel for this research and those attending research progress updates were critical to the correct development of the hotspot mapping process. They provide valuable input on species to include, areas to examine, the weaknesses of the data, how data were collected, and when the results of the modeling did not appear to accurately represent what they were seeing on the ground. Future iterations of hotspot modeling should be extremely transparent and done iteratively with agency personnel involved at each step.

The priority maps can be used to pinpoint specific areas where development could exacerbate the wildlife-conflict situation, and NDOT with partners can insist on measures to help relieve potential animal-vehicle conflict due to increase vehicles from the development. NDOT should develop a policy to encourage developers of subdivisions, strip malls, and other human dominated areas along NDOT roads to help pay for or upgrade wildlife mitigation in the area of development. For example, the Cold Springs Home Owners Association (HOA) has a mitigation account for wildlife. NDOW is working with Caltrans on fencing along US 395 near this neighborhood, which the HOA is expected to contribute funds. Occupancy permits, turning lane permits, driveways, roads, etc. can all be tied to the responsibility of the developer paying to mitigate the area for wildlife-or livestock-vehicle conflict.

Each NDOT District Will Need to Address Their Various Hotspots

The all-animal hotspot segments equal to or greater than two miles are considered the overall most important areas to reduce collisions with animals. Additionally, if the other hotspots could also be considered in upcoming NDOT projects or as standalone projects, specific types of animals could be kept off the roads and moving through or over crossing structures. Below, each district's hotspots from the overall statewide top 25 hotspots for different animal types and the safety and ecological hotspots are presented (Tables 32, 33, and 34). Additional steps on how these hotspots could be incorporated into the NDOT planning process area presented in chapter eight.

Table 32. NDOT District I Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse-Crash Hotspots, Cattle-Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
SR 375 Tikaboo Valley	US 93 LN 10-11	US 93 Caliente Newman Canyon	US 93 Newman Canyon	Extra Terrestrial Highway South Tikaboo Valley	US 93 Fairview Range
SR 160 Mountain Springs	SR 375 LN20-21	SR 160 Mountain Springs	US 93 North of Pioche	Extra Terrestrial Highway North Tikaboo Valley	SR 160 Mountain Springs
US 93 Pioche	US 93 LN 91.5-93.3	US 93 Pioche	US 93 East Pioche	Extra Terrestrial Highway Mid Tikaboo Valley	US 93 Lincoln-White Pine County Line
US 93 Wambolt Springs	US 93 LN 36-36.5	US 93 Wambolt Springs-Travis Reservoir	US 93 Caliente Meadow Valley	ARNY 44 Ralston Valley	US 93 Coyote Spring Valley
SR 159 Blue Diamond		US 93 Panaca	SR 360 Candelaria Hills	SR 361 North Gabbs	SR 318 Lund
		US 93 Caliente Meadow Valley	US 6 SR 360 Intersection	SR 170 Mesquite	
			US 6 Humboldt-Toiyabe National Forest	ARNY 44 Monitor Hills	
			US 6 Mineral Esmerelda County Line	US 95 South Mina	
			US 93 Grassy Springs Pioche	Extra Terrestrial Highway Railroad Valley	
			US 93 North Pioche		
			SR 264 Fish Lake Valley		

Table 33. NDOT District II Crash Hotspots 2007-2016 for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse Collision Crash Spots, Cattle-Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
US 395 Granite Peak	US 95A LY 34.4-36	US 395 Granite Peak	USA Parkway I-80 Junction and South	US 50 Lahontan Reservoir	USA Highway & I-80
USA Highway Clark Mountain	US 50 CH 23.2-24.3	SR 431 Mount Rose Foothills	US 50 Dayton	US 50A & US 95A South Fernley	US 95 Quinn River Valley
SR 431 Mount Rose Foothills	I-580 WA 5.2-6.7	I-580 & US 395A South Washoe Lake	US 50 Horse Fence End	SR 270 & 115 South Side of Fallon	US 50 Dayton
US 395A Pleasant Valley	US 50 LY 13-14.5	I-80 Stateline to Reno	US 50 Carson Plains	US 50 East Side of Fallon	US 50 Horse Fence End
US 50 Horse Fence End	US 50 LY 24-25	US 50 West Fallon	US 50A North of Silver Springs	US 95 Walker River	Mt. Rose Highway
US 50 Dayton	SR 445 WA 24.5-26	US 50 Fallon-Ragtown	US 50A South Fernley	SR 400 Dunn Glenn Flat	SR 445 Pyramid Lake
I-580/ US 395 South Washoe Lake	SR 118 CH 1.5-2	US 50 I-580 West Carson City	US 50 Carson Plains	SR 445 South Pyramid Lake	US 395 Carson River
US 50 West Fallon	SR 659 WA 2.4-3	US 95A Stillwater National Wildlife Refuge	SR 341 Virginia City	US 50 & SR 116 Fallon-Harmon Reservoir	I-580/395A Pleasant Valley
US 50 Carson Plains		US 395A Steamboat Hot Springs	SR 341 Steamboat	SR 117 West Edge of Fallon	
I-80 Stateline to Reno		US 95 Walker Lake	Mount Rose Highway	SR 447 East Pyramid Lake	
US 50 Fallon-Ragtown		US 50 & USA Highway Intersection		SR 121 Dixie Valley	

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
		US 395A Pleasant Valley		US 50A & US 95A Wabuska	

Table 34. NDOT District III Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Cattle	Safety and Ecological
I-80 Pequop Summit	I-80 EL 63.5 – 64	I-80 Pequop Summit	US 95 Oregon Border	US 93 Table Top Mountain
SR 227 Elko Hills	I-80 HU 12-13.5	I-80 Silver Zone	Grass Valley Road South Winnemucca	US 95 Quinn River Valley
SR 227 Spring Creek	I-80 EU 3-3.2	SR 227 Elko Hills	SR 789 Getchel Road-Kelly Creek	I-80 Moleen-Humboldt River
I-80 Silver Zone	US 93 EL 125-125.5	SR 227 Spring Creek	I-80 East Winnemucca	SR 227 Spring Creek Area
US 6 Western Eagan Range Foothills	I-80 EU 17.7-18.3	US 6 Western Eagan Range Foothills		US 93 North of Wells
US 95 Oregon Border	SR 157 CL 5-5.5	US 6 Steptoe Valley Wildlife Management Area		SR 227 Pleasant Valley
US 50 Eagan Range Robinson Summit	US 95 HU 39.5-41	US 95 Quinn River Valley		I-80 Pequop Summit
US 6 Steptoe Valley Wildlife Management Area	US 6 WP 56.5-58	US 93 HD Summit		I-80 West Elko
US 93 Travis Reservoir	I-80 EL 30-31	I-80 Humboldt River		US 93 Table Top Mountain S
	US 93 EL 67.5-EL 68	US 50 Eagan Range Robinson Summit		I-80 Silver Zone
	US 6 WP 8-8.5	US 93 Ten Mile Summit		I-80 Carlin
	US 6 W 8.5-10			SR 227 Lamoille

CHAPTER 4 EXAMPLES OF BENEFIT-COST ANALYSIS OF PAST AND UPCOMING WILDLIFE MITIGATION PROJECTS

Overview

Wildlife mitigation measures can be evaluated for their cost-effectiveness both prior to building and after placement. This exercise in evaluation is best applied to comparing among sites and evaluating potential costs and should NEVER be used as the sole criteria for building a wildlife crossing structure and other mitigation. It should be part of the overall evaluation. Ecological values such as intact mule deer herds and the protection of a population of endangered species of small animals are not quantified and brought into these equations. Thus, the benefit-cost analyses developed here are meant to help bring some understanding of the value of wildlife to wildlife mitigation. The equations used here are general equations and do not include discount rates, amortization over time, or any ecological values other than the potential average value of the wild animal killed. The results are not intended to support or discount particular projects in existence or in the future, merely to help inform. The existing wildlife crossing structures, existing structures that were part of a wildlife mitigation fence project, and fence projects are presented in Appendix F for assistance in locating wildlife and horse (equine) crossing structures and, dates they were installed, and other features.

Introduction

Cost-benefit is the framework for analyzing a range of benefits and costs in monetary terms, while the true equation is best represented by the term benefit-cost (Federal Highway Administration 2014). The guidelines for performing benefit-cost analysis to assess the value of wildlife mitigation projects are taken from previous work in Idaho (Cramer et al. 2014, Cramer 2016), and South Dakota (Cramer et al. 2016). This benefit-cost analysis involves steps outlined in Figure 40.

The inputs are placed into a benefit-cost equation, below:

$$\text{Benefit/Cost Ratio} = \frac{\text{Annual Potential Benefits x Percentage AVC* Reduction x No. Years Mitigation Lasts}}{\text{Estimated Project Cost + Maintenance Over Time}}$$

* AVC = Animal-vehicle collision

If the quotient value (benefit/cost ratio) is less than one, the project would cost more than predicted to benefit. If the quotient value was one, project is predicted to be break-even. If the quotient value were greater than one, the benefits would be predicted to outweigh the costs. The higher the quotient value, the greater benefit the project provides in relation to its costs.

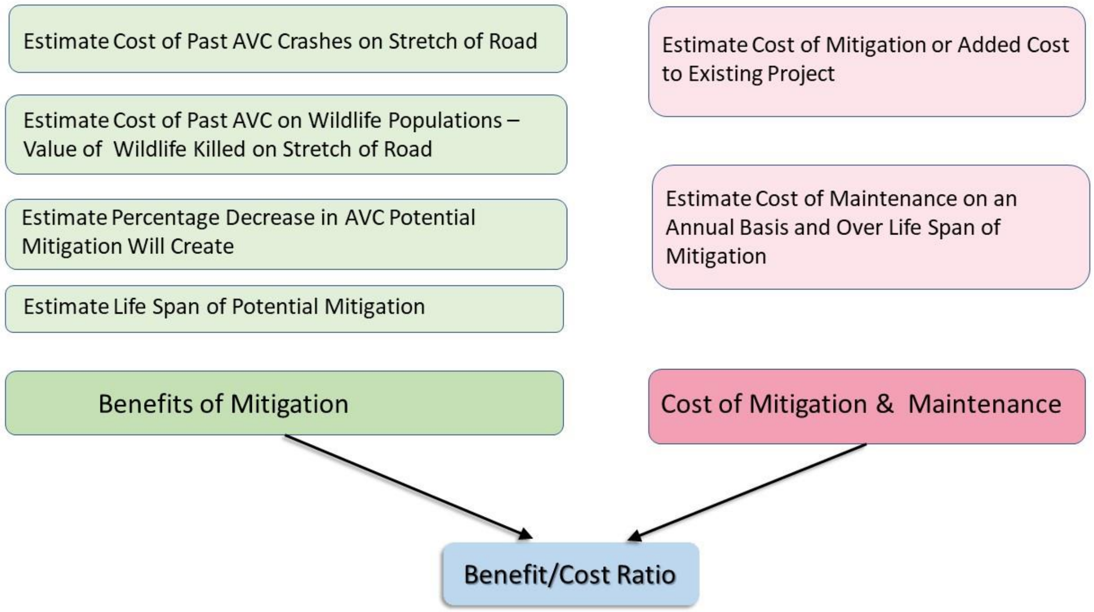


Figure 40. Benefit-Cost Analyses Inputs in This Report.

Methods

The benefit-cost analysis can also evaluate a project related to: how long it would take for project to pay for itself; or how much of a reduction in crashes the project would have to provide to pay for itself over the expected life of the infrastructure. The user will need to estimate the cost of potential wildlife mitigation, and the saved costs (benefits) to society from the action. The methods are organized into two main steps below:

1. Estimate the Benefits.
2. Estimate the Costs.

The estimates for the benefits and costs can be entered into an Excel worksheet prepared for this analysis. See the 'Worksheet for benefit-cost calculations' housed on the NDOT network.

Estimate Benefits

Estimate Cost of WVC from Reported Crashes

In Nevada the user will query the NDOT Traffic Safety app (Nevada Department of Transportation 2018b) or contact NDOT Safety Division database for reported animal-vehicle collision crashes and carcasses along the stretch of road of concern. The exact length of road, to the nearest mile post is chosen based where the wildlife or horse exclusion fence is proposed to be placed, plus one-tenth of a mile in each direction from the end of the fence. Users will query the crash database this length of road, to see how many animal-vehicle collision crashes have been reported in the past five years. The five-year period is chosen as the length of time to examine because this is the time-frame engineers in departments of transportation use to predict estimated future trends. The crash information includes the severity of each crash, which will be used to estimate costs of those crashes. The query can be done within Excel spreadsheets, or the shape files of the crash data, roads, and wildlife exclusion fencing can be used to determine the crash numbers.

Exact crash numbers can be determined from either Excel queries of the animal-vehicle collision crash database, or within ArcGIS. The ArcGIS method begins by selecting the crash data shape file layer developed in this study or future iterations of this research and using the selection tool to draw a box around the crash data points of interest and viewing the attribute table for those crashes. Each method must be used to select and retrieve all the records for the crashes under consideration. Each crash record has an entry column for the severity of the crash. Once that column is located, the user will need to tally the number of crashes delineated by each crash type in the selected segment of road under consideration.

Once the numbers of crashes are tallied for each crash type, an overall value will be given to those past crashes. The U.S. Department of Transportation (US DOT) FHWA estimated costs of crashes was updated in 2018 (Harmon et al. 2018). Crash costs include tangible consequences such as vehicle repair and replacement, emergency services, medical services, and lost wages, and intangible consequences such as pain and emotional suffering. The intangible consequences are monetized as are the tangible consequences, in the FHWA standardized values (Harmon et al. 2018). NDOT crash values are lower than the US DOT values, as are most state DOT values because each state adapts national standard values for their locality. The comparisons for crash values are presented in Table 35.

Table 35. Crash Incident Type and Costs Estimated by U.S Department of Transportation, Federal Highway Administration (FHWA) 2018, and Nevada Department of Transportation, 2016.

Type of Crash (Severity)	NDOT 2016 Value	FHWA 2018 Value*
Fatality	$ 5,839,241	$ 11,295,400
Type A Injury – Serious injury	$ 308,595	$ 655,000
Type B Injury – Visible injury	$ 112,708	$ 198,500
Type C Injury – Possible injury	$ 63,434	$ 125,600
Property Damage Only	$ 10,221	$ 11,900

** Based on the white paper: Harmon, T., G. Bahar, and F. Gross. 2018. Crash Costs for Highway Safety Analysis. Final Report to Federal Highway Administration Office of Safety.*

The user multiplies the Nevada values for each crash type by the number of those reported crashes over the time frame, for this case, five years. The user then divides the resulting five-year value of reported crashes by five for an annual average of the value of reported crashes (Table 36). The user then divides that annual number by the number of miles of road segment under investigation, to the nearest 1/10th of a mile. The final number is the annual cost per mile of animal-vehicle collision crashes.

A second analysis can also be conducted with the FHWA 2018 values. The above steps are the same, except the value of past crashes will be multiplied by the FHWA 2018 values also presented in Table 36.

Table 36. Benefit-Cost Analysis NDOT 2016 and FHWA 2018 Values for Crashes Worksheet.

Incident Description	Number of Reported Crashes	Nevada DOT 2016 Comprehensive Societal Cost Per Occurrence	Total NDOT Value	FHWA 2018 Crash Values	Total FHWA Crash Values
Fatal		$ 5,839,241		$ 11,295,400	
Serious Injuries (Type A)		$ 308,595		$ 655,000	
Visible Injuries (Type B)		$ 112,708		$ 198,500	
Possible Injuries (Type C)		$ 63,434		$ 125,600	
Property Damage Only (PDO)		$ 10,221		$ 11,900	
Total Value of Crashes – All Data (Sum Total values column(s)					
Total Annual Value = Total Value / Number of Years of data					
Annual Cost per Mile = Total Annual Value/Number of Miles					

Estimate Cost of Animal-Vehicle Collisions on Wildlife Populations

There is a value to the residents of Nevada, of every individual wild animal. This was established by Nevada penal code for prosecution of poachers of wildlife, see Table 37 below. The user will need to first estimate how many wild animals were killed by crashes, and then place a value on those animals. The number of the wild animals killed can be estimated with two methods: either from carcass data or by taking animal-vehicle collision crash data and multiplying it by a correction factor.

Nevada carcass data have been collected inconsistently across the state. In places and over time frames where the carcass data were collected consistently, users can estimate the value of the animals collected by analyzing carcass records for the species and gender of the animals and placing a value on each type. If the carcass data in a specific place appears to be collected consistently, the user can follow the instructions under the sub-heading, *Estimate Wildlife Value Through Carcass Data*, below. If data is sparse, users can use the method in the second subsection, *Estimate Wildlife Value Through Crash Count Multiplier*, below.

Table 37. Value of Individual Animals of Different Wildlife Species, from Nevada Department of Wildlife, Courtesy of Game Warden Captain Michael Maynard, September, 2017.

Category	Minimum Each Animal	Maximum Each Animal
Trophy Big Game	$ 5,000	$ 30,000
Big Game	$ 250	$ 4,999
Bobcat/Swan/Eagle/Moose	$ 250	$ 4,999
Other Wildlife	$ 25	$ 1,000

Estimate Wildlife Value Through Carcass Data

If the carcass data appear to be collected consistently (see below), the user can use this method to estimate the value of wild animals killed along the road. The user will need to examine first five years, then 10 years of carcass data to determine if the data are consistent enough for inclusion in the benefit-cost analysis. If there is a trend of decreasing carcasses over the past five years, a ten-year time frame will be examined to calculate a more accurate carcass annual average then the five-year may have produced. In the future as NDOT and NDOW improve carcass documentation, the five-year time-frame should be reinstated for carcass data analyses for wildlife valuation. NDOW's Game Warden, Captain Michael Maynard provided Nevada state values of individual wild animals in the case of prosecution of wildlife poachers (Table 37, above). These are values for court determined costs of poached animals. In initial benefit-cost analyses for this chapter, the range of animal values for the different species was used to estimate the value of animals. The range of values from $250 to $ 30,000 proved to be too great to provide value for the benefit cost equation, since there was a 120 times difference in values. As a result, all ungulates (hooved animals) are given a value of $1,000, mountain lions and bears a value of $500 each, and bobcat a value of $750. The $1,000 value is typical of how South Dakota (Cramer et al. 2016) and Idaho (Cramer et al. 2014, Cramer 2016) valued their wildlife species in poaching cases, and what was used in benefit-cost calculations cited studies in those states.

The number of carcasses collected of the three different animal types is then multiplied by the values given above, to create a total value of carcasses collected over the time frame examined. This provides the cost over all the years. The total carcass value per year is calculated by dividing the total carcass value by number of years the data were obtained from in the database. That annual value is then divided by the total number of miles. The resulting value is the annual value of carcass per mile in the stretch of road analyzed. A worksheet is provided in Table 38, below.

Table 38. Worksheet for Individual Wildlife Species Carcass Values.

Species of Carcasses	Number of Carcasses	Value of Individual Animal Killed	Total Value of Animals Killed
Ungulates		$1,000	
Bear/Puma/Coyote/Other		$ 500	
Bobcat		$ 750	
Total Carcasses & Costs over X years			
Total Carcasses/mile/year			
Total Annual Value of Animals Killed			
Carcass Value /mile /year			

Estimate Wildlife Value from Crash Count Multiplier

If the carcass data are collected inconsistently, the user can use this method to get a rough estimate of the value of wild animals killed along the road. The second method to value the wild animals killed by vehicle crashes in the segment of road under consideration is to take the total number of crashes reported with wildlife in an area, and multiply by 5.26. This was the correction factor estimated by Olson (2013) and Olson et al. (2014) for the number of carcasses of mule deer and other wildlife as related to the number of reported WVC crashes in Utah. This adjusted number is then multiplied by $1,000 for an overall average of all types of wild animals killed in vehicle crashes. This $1,000 value is typical of how South Dakota (Cramer et al. 2016) and Idaho (Cramer et al. 2014) valued their wildlife species in poaching cases, and what was used in the cited studies in those states.

Estimate the Percentage Decrease in Animal-Vehicle Collision Crashes

Huijser et al. (2009) analyzed 10 wildlife mitigation studies and their reductions in wildlife-vehicle collisions and found an average of an 86 percent reduction in either wildlife-vehicle collision crashes or carcasses. There are typically three different levels of expected reductions in wildlife-vehicle collision from mitigation:

1. 50 percent as used by Oregon DOT in the Lave Butte Project near Bend, as derived from their benefit-cost analysis;
2. 75 percent which is the typical portion estimated for most wildlife-vehicle collision mitigation;

3. Or as much as 90 percent, which was the actual amount of wildlife-vehicle collision crashes reduced in a project in Utah and others.

The analysis can be performed with three different equations, each one with a different level of reduction of animal-vehicle collision crashes (.50, .75, and .90 reductions). These different equations can then be instrumental in helping to decide how much animal-vehicle collision reduction is needed for the treatment to be considered cost-effective. Note, if the projected mitigation action is not a set of wildlife crossing structures with wildlife fencing, the anticipated reduction in animal-vehicle collision would be significantly lower than a 90 percent estimate.

Estimate the Lifespan of the Mitigation and Calculate Benefits Over Time

Structures such as bridges and culverts are built to last 50 to 75 years. Fences may have a shorter lifespan if the quality is not to high standards. Benefit-cost analyses can be worked with both 50 and 75 year life of the structures to evaluate how this affects the benefit-cost ratio.

Create the Numerator - Calculate Projected Benefits Over Time

Benefits = (Annual Cost of animal-vehicle collision crashes/mile from Crash Data + Cost Estimated from Carcass Data/mile) x number of miles of fence and mitigation x Percent Reduction in animal-vehicle collision crashes x Life Span of Mitigation.

Estimate Costs

Estimate Cost of the Mitigation

The cost of wildlife mitigation can be estimated through consultation with NDOT staff and past mitigation costs records. The cost can also be slightly informed from the cost estimates in Table 39, below.

The cost of mitigation should include how much extra the wildlife mitigation would add to an existing project, or the costs of a standalone project. For example, if a culvert is enlarged to accommodate wildlife, the difference in cost from a culvert that would have been installed for other needs is subtracted from the cost of a larger culvert that is built to accommodate wildlife. Costs of fencing, escape ramps, and wildlife guards or double cattle guards also need to be brought into the cost estimates. In addition, annual cost for maintenance of the structure or fencing needs to be incorporated into the final cost over the lifetime of the structure.

Table 39. Worksheet of Gross Cost Estimates of Potential Wildlife Mitigation. Based on P. Cramer Work in Western U.S. States. Cost estimates are in U.S. Dollars.

Animal-Vehicle Collision Reduction Alternative	Gross Estimated $ Cost Per Unit	No. of Units	Total Cost
Actions that Target Drivers			
Animal Detection-Driver Warning System Based on Thermal Cameras, Radar, over miles	~ $ 2.5 million		
Driver Warning Signs/Variable Message Boards	$ 30,000		
Public Education & Awareness Campaign	$ 5,000		
On Site Kiosks to Educate Motorists	$ 2,500		
Motion Stimulated Warning Signs w Speed Clocked and Warnings	$ 5,000		
Enforcement in Wildlife Speed Reduction Zones	Not NDOT Cost		
Speed Reduction Zones	Minimal		
Vegetation Management - Removal	$ 2,000/mile		
Roadside Treatment - Lighting	$ 10,000/mile		
Actions That Target Wildlife			
Retrofit Existing Bridges-Culverts and Fences – This May Include Adding Fencing	Variable 1,000 to 5,000 dollars		
Exclude Wildlife From Road with Fence, Provide Wildlife Underpass, Escape Ramps, Deterrents at Vehicle Access Points			
Wildlife underpass: $ 500,000 - $ 1.2 million for 4 lane road	$ 500,000 – 1.2 million		
Wildlife Overpass from $2 million for a 2 lane road, to $8 million for a 4 lane divided interstate			
Fencing $100,000 per mile OR $7 per foot (5,280 feet/mile x $7 = $37,000 per mile one side of the road, $74,000 / mile, both sides)	$ 100,000/mile		
Double Cattle guard: $25,000 for driveways, upwards of $60,000 for roads and interstate entrance and exit ramps	$ 25,000 – 60,000		
Escape Ramps $15,000 - $30,000 each	$ 15,000 each		
Annual Maintenance for Fence, Structures, etc.	$ 500/mile of fence/year		
Total for system of fencing, structure, escape ramps, and double cattle guards or electric pavement			

Determine Benefit-Cost Ratio

Place benefit values in the numerator, and costs in the denominator. Find the quotient. The resulting quotient is reflective of the predicted cost-effectiveness. The goal is to have a ratio of one or greater for a project. This value does not predict future crash numbers or increasing costs of crashes. Thus, it is not a standalone value determining value of the potential mitigation

Determine How Long Would It Take for Project to Pay for Itself

The potential project can also be analyzed for the expected amount of time it would take to pay for itself. The benefits value of reduced animal-vehicle collisions averaged each year is divided into the expected cost to see how many years of savings would add up to the total cost, and thus a quotient of one.

Benefit-Cost Analysis for Four Projects

The panel and research team chose two existing and two future wildlife mitigation projects within Nevada to quantify their value with a benefit-cost analysis. Using animal-vehicle collision crash and carcass data, the average annual value of these crashes was estimated for each project area. For established mitigation projects, the costs were obtained from NDOT personnel. The projects analyzed were:

- US 6 in White Pine County – future project;
- I-80 Pequop Summit – under construction during this research;
- US 93 HD Summit and 10 Mile Summit; and
- US 50 Horse Fencing Projects Near Dayton.

Results

US 6 Near Ely in White Pine County – An Example of Comparisons Among Potential Projects

NDOT project manager for this research, and a member of NDOT environmental staff, Ms. Nova Simpson, requested that a potential project along US 6 around Ely Nevada be selected based on reviewing three road segments and calculating the best return for dollars potentially invested in reducing animal-vehicle collision crashes in this area. Fortuitously, this was a wise selection because two areas near Ely became numbers 17 and 21 of the top 25 hot spots for animal-vehicle collision crashes in Nevada. This is an area where the maintenance staff have been more consistent about documenting animal-vehicle collision carcasses over the last several years, thus the carcass data set is robust. There were no plans to address wildlife-vehicle conflict in this area at the time of this writing, but it was thought this analysis could perhaps generate some generic costs if NDOT were to place a wildlife crossing overpass and fencing in each of the hotspot areas. Overpass structures are being assessed for this location as the topography of this mountainous area does not tend to lend itself to underpasses. The three segments were designated: West Section US 6 MM 29-37; East Section US 6 MM 42-46 (Figure 41); and the Schell Creek Mountains Section, US 6 MM 56-66 and US 93 MM 25-26.7 (Figure 42).

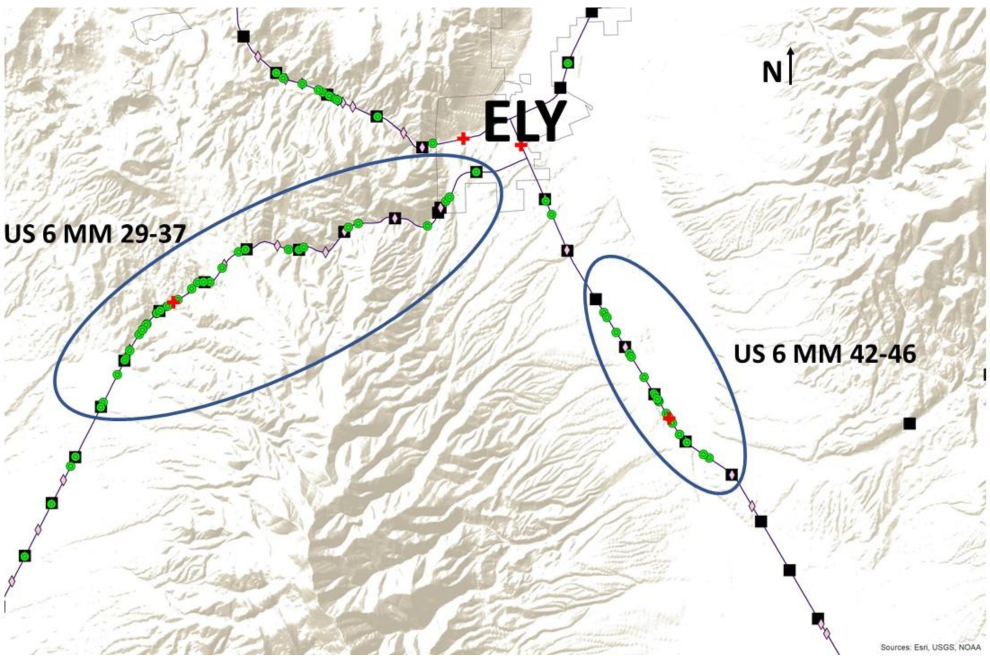


Figure 41. US 6 West Section and East Section, Near Ely, Nevada.

US 6 West Section MM 29 – 37

This is the Eagan Mountain Range Area. Crashes from 2006-2015 totaled 36 reported crashes with animals over the six miles. Twenty accidents were with deer, five were reported with elk, one with a cow, and one with bighorn sheep. The remaining accident reports did not indicate the species involved. Thirty-four of the accidents were PDO. One was a Type B Injury accident, one was Type C injury. The total NDOT crash value of these crashes was $ 523,656. The FHWA Value was $ 728,700. Total NDOT annual cost per mile = $ 6,546. Total FHWA annual cost per mile = $ 9,109.

The carcasses included: 25 deer, 7 elk, and 2 pronghorn for a total of 34 animals collected. Using the $1,000 average value for each animal, this came to $ 34,000 over the time period and stretch of road, and $472 annually per mile. The estimated annual value of wildlife killed per mile derived from using solely crash data was $ 450.

US 6 East Section MM 42-46

This four-mile section contains the Steptoe Valley Wildlife Management Area. Crashes from 2006 - 2015 – there were 19 reported wildlife related crashes over the four miles. Seven of the crashes were reported with deer, nine with elk, two with pronghorn antelope, and one with a coyote or dog. All 19 crashes were PDO. The total NDOT value of these crashes was estimated at $ 194,199. The total FHWA value for these crashes was estimated at $ 226,100. The NDOT annual cost of these crashes per mile was $ 4,855. The FHWA annual cost per mile was $ 5,653.

The carcasses included: four deer, four elk, and one pronghorn for a total of nine wildlife carcasses. The cost of these was estimated at $ 9,000. The cost of carcasses annually per mile was estimated at $ 250. The estimated annual value of wildlife killed per mile derived from using solely crash data was $ 450.

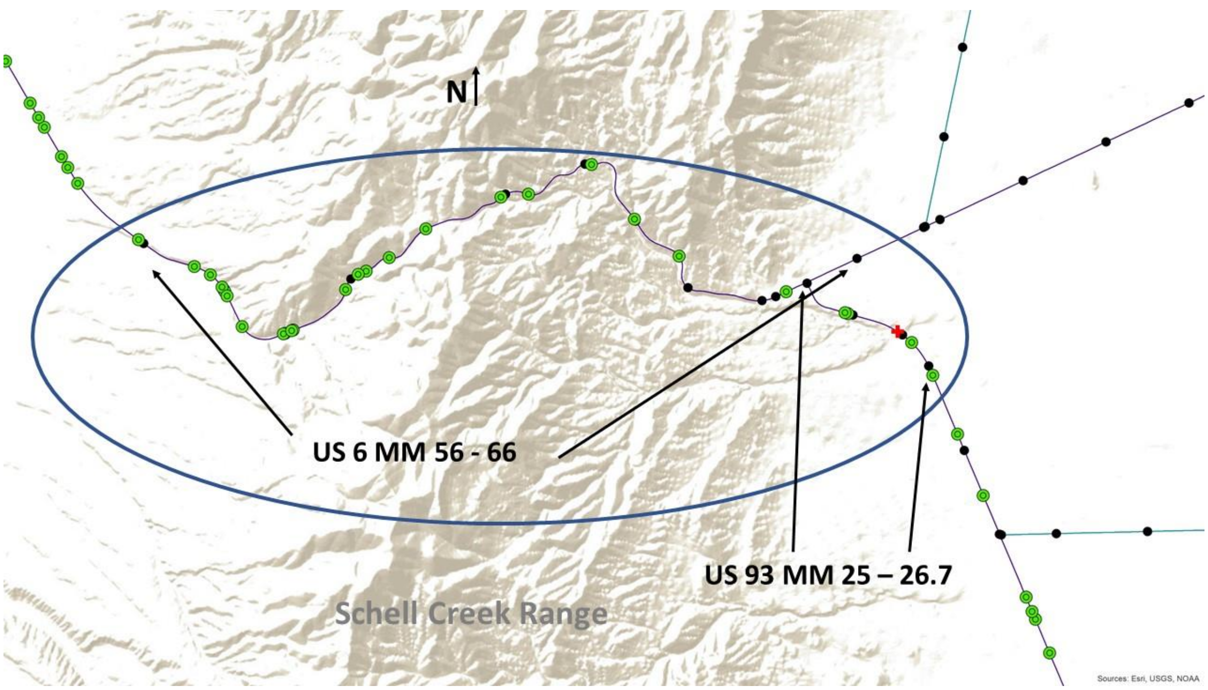


Figure 42. US 6 and US 93 Road Segments that Comprise the Schell Creek Mountains Section.

US 6 and US 93 Schell Creek Mountain Range Section US 6 MM 56 – 66, US 93 MM 25 - 26

The two highways in this area total 11.7 miles (Figure 42). From 2006 – 2015 there were 23 crashes reported with wildlife: eleven with deer, eleven with elk, and one unreported wild animal. Twenty-one crashes were PDO, two were Type B Injury crashes. US 93 and US 93 N MM 25-26; there were four reported crashes with wildlife, three deer and one elk. All were PDO crashes. The NDOT total crash value was $ 480,941. The FHWA total crash value was $ 694,500. The NDOT annual crash value per mile was $ 4,111. The FHWA annual crash value per mile was $ 5,936. There were 15 reported deer carcasses, and 13 elk. The value of these is estimated at $ 28,000. The annual cost per mile for carcasses was $ 239. Using the carcass value estimated from crashes, it was $ 231 per mile per year, very close to the actual carcass cost.

Comparison of the Three US 6 Sections in Benefits

Once each site had calculations for the values of what the costs were per mile per year for crashes and carcasses, a side by side comparison of those costs, and ultimately potential benefits for reducing those costs can be made. The more expensive the cost of crashes and costs, the greater potential a site has for wildlife mitigation to be cost-effective. Table 40 demonstrates several of the values of this type of calculation.

Table 40. Comparison of Crash and Carcass Costs Among Three US 6 Sections.

Name	Section Number of miles	Number crashes w wildlife	Number Crashes per mile per year	Total Cost of Crashes per mile per year	Number of years of carcass data	Total carcasses	Number of carcasses per mile per year	Annual cost of carcasses per mile	Rankings by Categories
US 6 West	8	36	0.45	$6,545	9	34	0.53	$ 450- $472	Number 2 for crashes /mile, and Number 1 for crash costs. Number 1 for carcasses
US 6 East	4	19	0.48	$4,855	8	9	0.28	$250 - $475	Number 1 for crashes/mile, Number 2 for Crash costs, Number 2 for crashes, Number 2 for carcasses
US 6 - US 93 Schell Mtns.	12.7	25	0.20	$3,787	10	28	0.22	$231 - $239	Last for crash, 2 or last for carcasses

When US 6 West and East are compared, US 6 West had a greater cost of crashes with animals per mile per year ($ 6,546), yet a lower rate of crashes per mile per year (0.45) as opposed to US 6 East costs ($ 4,855) and rate (0.48). The total value of the US 6 West site is $ 6,546 for crash values + $ 472 for carcass values = $ 7,018 per mile per year. The comparable value for US 6 East is $ 5,105 per mile per year. The comparable costs for the Schell Mountains section was $ 4,350 per mile per year. The US 6 West Section would pay a higher return on the same investment of wildlife mitigation.

The West Section's benefit values for crashes and carcasses avoided annually with potential mitigation can be calculated to an annual cost savings for a potential project. The potential project would be eight miles in length. The predicted annual costs of crashes and animals killed in that eight miles is estimated at 8 x $ 7,018 = $ 56,144. If a mitigation project is predicted to reduce crashes by 90 percent, and the project infrastructure is expected to last 75 years, then the benefit of a wildlife mitigation project here would be: ($ 56,144 x 75) x 0.9 = $ 3,789,720. This means that this eight mile stretch of US 6 has enough animal-vehicle collision crashes and carcasses recorded that if a mitigation project were constructed that cost as much as $ 3.80 million, it would pay for itself over 75 years. This analysis is an extreme simplification of the many factors that would go into a detailed analysis. It is however, an example of how quickly NDOT personnel could conduct such a benefit-cost analysis.

If FHWA crash values are used to estimate value of animal-vehicle collision crashes, the annual cost per mile for crashes was $ 9,109 which would equal $ 72,872 for the eight miles. When the value of animal carcasses collected is added ($ 472 per mile x 8 miles = $ 3,776), the annual crash and animal value of the six miles calculates to $ 76,648. If the mitigation is expected to reduce animal-vehicle collision crashes by 90 percent, and the structures last 75 years, the benefits of the mitigation in prevented animal-vehicle collision crashes are: $ 76,648 x 75 x 0.90 = $ 5,173,740. The FHWA value would then demonstrate added value of the mitigation, and using these figures would help demonstrate a 37 percent increase in the value of the potential wildlife mitigation structures.

The equation to calculate the potential value of a possible mitigation is:
Potential Value of Wildlife Mitigation = (Annual Average Crash cost per mile + Annual Wild Animal cost per mile) x Number of Miles of Project x Number of Years Mitigation is Expected to Last x Expected Percentage Reduction in AVC.

I-80 Pequop Summit 2017 Project

In 2016 NDOT began construction what was at the time the top wildlife-vehicle collision crash hot spot in Nevada. The I-80 Pequop Summit project was completed during this study, in late 2017. The mitigation was installed to assist the northeastern Nevada mule deer herd that migrates across US 93 and I-80 to winter and summer ranges. The mitigation is from MM 89 to 100 (Figure 43), but the fencing extends from MM 90.1 in the west to MM 99.7 in the east, so total miles to analyze equal 9.6 miles. There were two new wildlife overpass structures built into this project. This is the only location known in Nevada where maintenance crews have been diligent in documenting wildlife collisions carcasses over the last several years. There will only be pre-construction data on carcasses and crashes, but that allows for a comparison to look at how many years it would take for the mitigation to pay for itself with the decreases in animal-vehicle collisions. The cost for that project was approximately $14.1 million (Table 41).

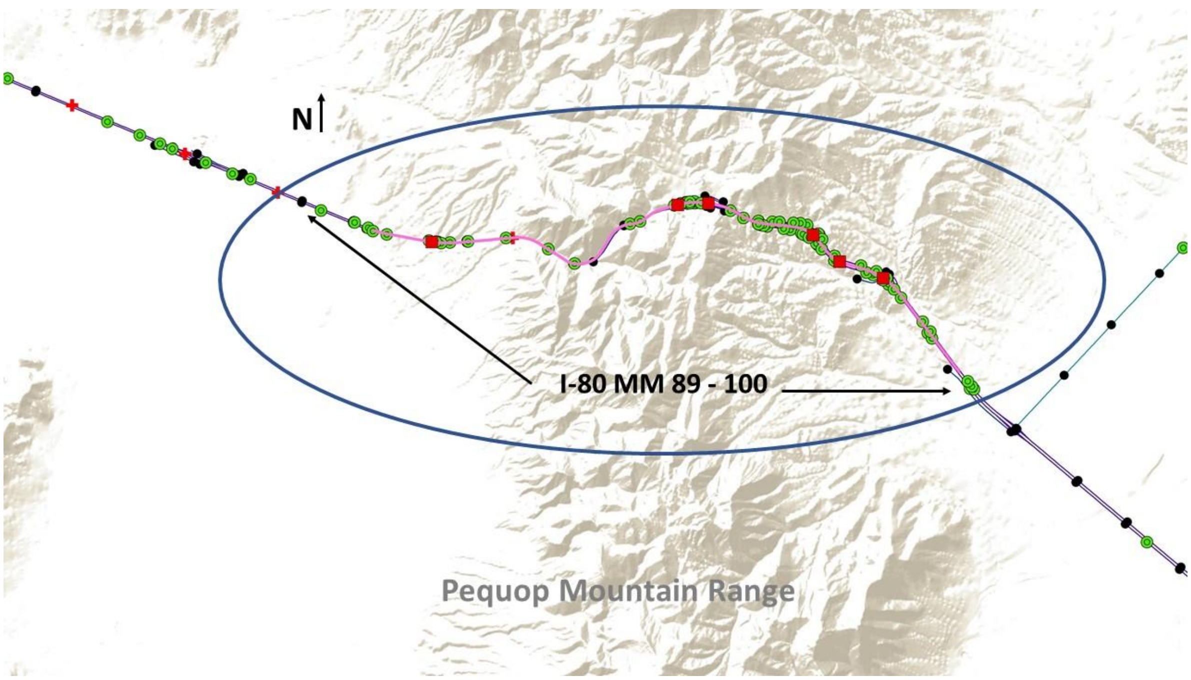


Figure 43. I-80 Pequop Summit Project.
Pink Line Represents the Wildlife Exclusion Fence, Red Squares Represent Wildlife Crossing Structures and Existing Culverts, Green Dots Represent Animal-Vehicle Collision Crashes, Black Circles are Mile Markers.

Table 41. Approximate Costs for I-80 Pequop Summit Wildlife Mitigation Project.

Structure and Fencing	MM	Fence Length	Notice to Proceed	Approximate Completion	Cost
1 Steel Overpass	91		3/2016	12/2017	
1 Steel Overpass	97		3/2016	12/2017	$ 12,900,00 for both
Fencing		9.6 x 2 sides = 19.2 Miles	3/2016	12/2017	$ 1,200,000
Total					$ 14,100,000

Reported Crashes I-80 MP 89 – 99.7 (10.7 miles) Pequop Mountain Range, 2007-2016: There were 94 reported crashes with wildlife and livestock from 2007-2016. Eight injury crashes (7 C, 1 B), 86 PDO. Total crash value with NDOT values = $ 1,435,752. Crash value with FHWA values = $ 2,101,100. Annual crash cost per mile with NDOT values = $ 14,651. Annual crash cost per mile with FHWA values = $ 21,440.

Carcasses 2006-2015 = 210 deer, 2 elk, 1 mountain lion. Total value of wildlife = $ 212,750. Annual value of wildlife per mile = $2,171. Value of carcasses estimated from crash data = $ 959 per mile per year.

Cost of maintenance is estimated at $1,000 per year. For an estimated lifespan of 75 years, this would equal $75,000

Benefit/Cost Estimate with NDOT values: Benefit / Cost =
($ 14,651 + $ 2,171) x 9.8 miles x 75 years x 0.9 reduction / $ 14,100,000 + $ 75,000
$ 10,900,299 / $ 14,175,000 = 0.769

Benefit/Cost Estimate with FHWA values: Benefit / Cost =
($ 21,440 + $ 2,171) x 9.8 miles x 75 years x 0.9 reductions / $ 14,100,000 + $ 75,000
$ 15,299,743 / $ 14,175,000 = 1.079

The Pequop Summit project would not be expected to pay for itself in 75 years using the NDOT crash values but would be expected to pay for itself using FHWA crash values.

US 93 Wells Crossings Ten Mile Summit and HD Summit Projects

Thousands of mule deer migrate biannually across US 93 and I-80 to their summer and winter ranges in Northeast Nevada (NDOT District III). Through the use and analysis of GPS collared mule deer movements in the migrating herds and crash and carcass data, the locations for the two wildlife overpass structures and four wildlife underpass structures were chosen on US 93. The mitigation was installed in two projects, the Ten Mile Summit (MM 81-85.7), from June 2009 through August 2010, and the HD Summit (MM 88-94.5) from February 2010 through October 2016. The Ten Mile Summit Project had four miles of wildlife fencing installed on both sides of US 93, and the HD Summit Project had 6.5 miles of fencing on both sides of the road (Figure 44). The total projects' combined lengths were 10.5 miles. The cost of the two projects was approximately $ 10,840,067, see Table 42 for Ten Mile Summit costs, and Table 43 for HD Summit.

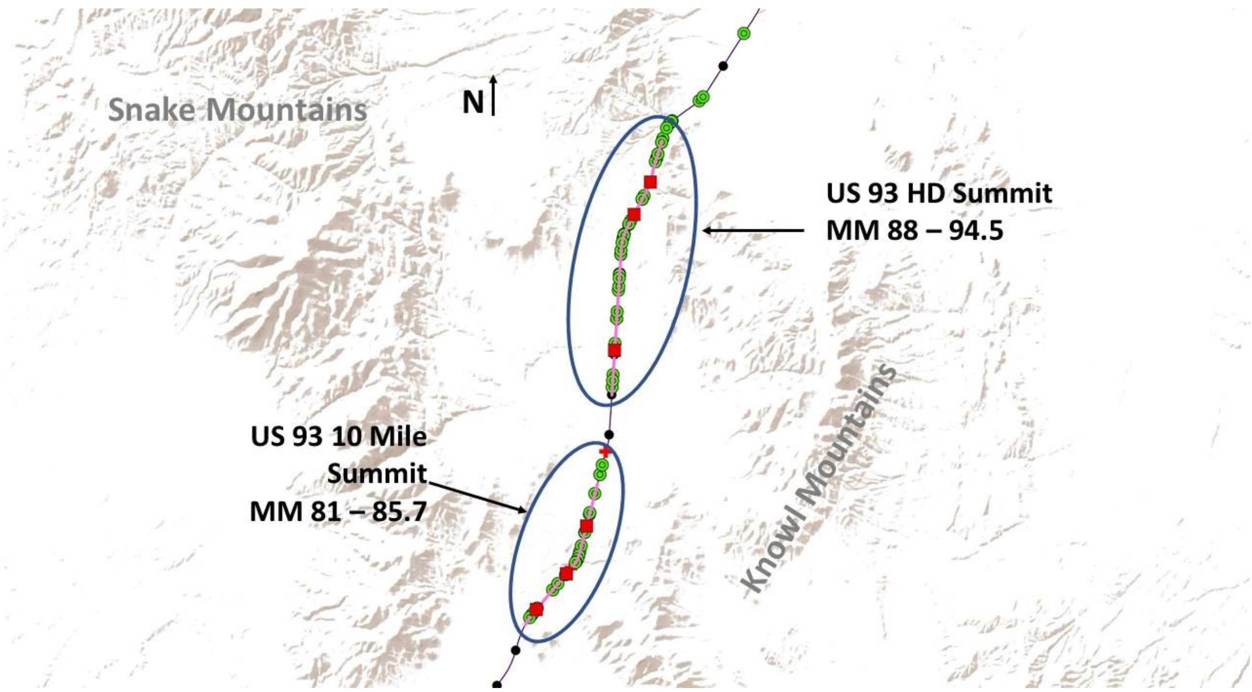


Figure 44. US 93 Wells Crossings Ten Mile Summit and HD Summit Projects' Maps.

Table 42. US 93 Ten Mile Summit Project (Mile Markers 81.7-85.7) Costs.

Structure and Fencing	MM	Fence Length	Notice to Proceed	Approximate Completion	Cost
10 Mile Summit					
1 Overpass	83		9/2009	8/2010	$ 1,900,000
Fencing NDOW Paid, estimated cost		4 miles x 2 sides = 8			$ 350,400
2 Corrugated Metal Underpasses	82,85		12/2009	8/2010	$ 2,133,000
Total					$ 4,383,400

Table 43. US 93 HD Mile Summit Project (Mile Markers 88-94.5) Costs.

Structure and Fencing	MM	Fence Length	Notice to Proceed	Approximate Completion	Cost
HD Summit					
1 Overpass + Fencing (this is the way the numbers came in)	93	3.5 miles x 2 = 7	2/2010	8/2010	$ 3,200,000
1 Concrete Underpass + Fencing	89	3 miles x 2 = 6	6/2015	10/2016	$ 2,200,000
1 Corrugated Metal Underpass	92		6/2015	10/2016	$ 1,066,667
Total					$ 6,466,667

Crash data

There are two methods to gather the crash data: with the animal crash Excel database, or with the ArcGIS shapefile of the 2007-2016 animal crashes. These estimates were taken from the 'Select' function in the ArcGIS shape files for cumulative mile markers and the 2007-2016 animal crash data point file. Through this method, the location of the exact beginning and end of the project can be located, crashes within those boundaries selected, and the attribute table of those crashes can be opened up and examined for the information pertaining to all the crashes.

US 93 Ten Mile Summit from MM 81-85.7, from 2006 to 2016 Crashes:
Pre-Construction 2006 – 2009, MM 80.9 – 85.8 (0.1 of a mile beyond future fence end)
12 crashes 2006-2009 pre-construction: 1 A injury, 1 C injury, 10 PDO;
Post-construction 2011-2016: 9 crashes: 1 C injury, 8 PDO.
There was a 25 percent decrease in crashes.
Cost of crashes pre-construction: Total NDOT crash value = $ 474,239. Cost of crashes per year per mile with NDOT values = $ 25,225. Total FHWA value = $ 899,600. Annual FHWA cost per mile = $ 47,851.

US 93 HD Summit MM 88 - 94.5
Pre-Construction 2006 – 2010, MM 87.9 – 94.6 (0.1 of a mile beyond future fence end)
13 crashes, all PDO. Over 5 years, this equates to 2.6 crashes
During Construction 2011 – 2014: 18 crashes, 2 injury crashes, 16 PDO.
Post Construction 2015-2016: 6 PDO crashes. This equates to 3 crashes per year.
First two years post-construction, no decrease in reported crashes.
Cost of crashes pre-construction : Total NDOT crash value = $132,873. Cost of crashes per mile per year = $ 3,966. Total FHWA value = $ 154,700. Annual FHWA cost per mile = $ 4,618.

Carcass Data
US 93 Ten Mile Summit MP 81 – 85.7 2006-2009 Pre-construction carcass data 2006-2009
Pronghorn= 1, Mule Deer = 29, Elk = 3. Total wildlife value = $ 33,000 over four years. Annual value of wildlife per mile = $ 1,755.

US 93 Ten Mile Summit MP 81 – 85.7 2006-2009 Post-construction carcass data 2010-2015
Mule deer = 1, Elk = 2.

US 93 HD Summit MP MM 88-94.5, 2006-2009 Pre-Construction carcasses
Deer = 31. Total value of deer = $31,000. Annual value of deer per mile = $ 1,192.

Benefit/Cost for Ten Mile Summit with NDOT Values
Note, since there was not a substantial crash reduction post-construction in the first five years post-construction, the percent reduction expected in the future is set at 75 percent rather than 90 percent: Benefit / Cost =
($ 25,225 + $ 1,755) x 4.7 miles x 75 years x 75% reduction / $ 4,383,400 + ($ 500 x 75);
$ 7,133,048 / $ 4,420,900 = 1.613 The mitigation is expected to pay for itself over 75 years, with a 75 percent reduction in crashes, using NDOT crash values.

Benefit/Cost for Ten Mile Summit with FHWA Values
Benefit / Cost = $ 13,114,688 / $ 4,420,900 = 2.967 The mitigation is expected to pay for itself. It could pay for itself more quickly than 75 years, and with a greater animal-vehicle collision crash reduction of 90 percent. The structures and fencing are expected to pay for themselves. The mitigation would pay for itself in less than 43 years under the NDOT values, and in less than 21 years with the FHWA values.

HD Summit NDOT Values

Benefit / Cost = ($ 3,966 + $ 1,192) x 6.5 miles x 75 years x 90% reduction/ $ 6,466,667 + (75 x $ 500);
$ 2,263,365 / $ 6,504,167 = 0.348 The mitigation is not expected to pay for itself over 75 years, with NODT crash values.
Benefit/Cost for HD Summit with FHWA Values
Benefit / Cost = $ 2,549,233/ $ 6,504,167 = 0.391. The mitigation is not expected to pay for itself over 75 years with FHWA crash values.

Using these benefit-cost equations and values, the Ten Mile Summit mitigation project would be expected to pay for itself, with NDOT cost-benefit value of 1.613, and a FHWA value of 2.967. If the benefits of the Ten Mile Summit project were expected to reduce animal-vehicle collision crashes by 75 percent, and the value of prevented crashes was $25,225 per mile per year (NDOT values), the cost of the mitigation and maintenance was $ 4,420,900 for the 4.7 miles of mitigation, an equation can be created to examine how quickly the mitigation would pay for itself: $ 4,420,900 / ($ 25,225) x 4.7 x .75 = 49.7 years.

With FHWA values, the Ten Mile Summit mitigation can be expected to pay off in 26.2 years.

The HD Summit would not be expected to pay for itself over 75 years, with benefit-cost ratios of 0.348 for NDOT crash values, and 0.391 using FHWA values.

US 50 Horse Fencing Project Near Dayton and USA Parkway Horse Mitigation

Horses play a major role in animal-vehicle collisions east of Carson City, Nevada. NDOT placed horse mitigation on two roads in this area over three construction projects, Figure 45. The US 50 2013 Horse Mitigation Project placed a concrete box culvert for horses, along with horse fences from MM 13.75 to 17.50. This project cost $ 1.4 million. In 2016 NDOT placed fence along US 50 from MM 17.50 to 20.30, and 26.25 to 29.20, at a cost of $ 750,000. The third project was placed in conjunction with the completion of a new highway, SR 439, the USA Parkway. There, two horse box culverts were placed, along with horse fence for 15.5 miles. These were placed at a cost of $ 2,876,000. Each mitigation project was analyzed separately for benefit-cost. See Table 44 for each project's costs.

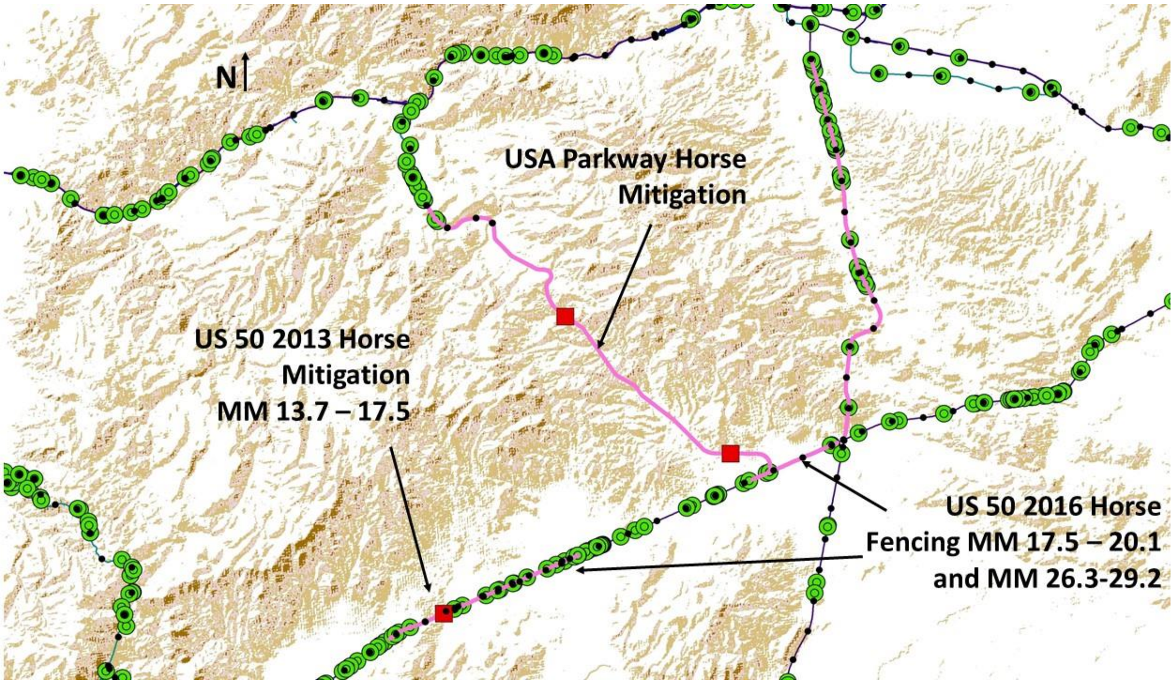


Figure 45. USA Highway Horse (Equestrian) Mitigation Fencing and Box Culverts.

Table 44. US 50 and USA Parkway Horse Mitigation Costs.

Structure and Fencing	MM	Fence Length	Notice to Proceed	Approximate Completion	Cost
US 50 2013 Horse Mitigation					
US 50 Horse box culvert	15		6/2012	8/2013	$ 600,000
US 50 Fencing MM 13.75-17.5	LY 13.75 – 17.5	3.75 x 2 = 7.5 miles	6/2012	8/2013	$ 800,000
Total US 50 Horse Mitigation					$ 1,400,000
US 50 2016 Horse Fencing					
Fencing 17.5-20.3 and 26.25 – 29.20	17.50-20.30 & 26.25-29.20	2.8 x 2 + 2.95 x 2 = 11.5	6/2015	9/2015	$ 750,000
USA Parkway Horse Mitigation					
2 concrete box culverts for horses			1/2017	8/2017	$ 1,126,000
Fencing		15.5 miles x 2 = 31 miles	1/2017	8/2017	$ 1,750,000
Total USA Parkway Mitigation					$ 2,876,000

US 50 2013 Horse Mitigation MM 13.75 – 17.6 Benefit-Cost Equation

US 50 2013 Horse Mitigation Crashes MM 13.75 – 17.5

Pre-Construction 2006-2011 - 12 crashes, 2 cows, 10 horses, 3 Injury B, 3 Injury C, 6 PDO.

Post-Construction 2012-2016 - 5 crashes, 3=horses, 1= deer, 1=black bear, all PDO.

US 50 2013 Horse Mitigation MM 13.85 to 17.60, Pre-Construction 2006-2011 Carcasses
13 Deer, 5 Horses.

US 50 2013 Horse Mitigation MM 13.85 to 17.60, Post-Construction 2013-2015 Carcasses
2 Deer, 1 Horse.

NDOT Values Benefit-Cost Equations

NDOT total value of crashes pre-mitigation = $ 589,752. Crash value per year per mile = $ 24,573. Carcass value of wildlife killed per year per mile = $ 542. Benefit / cost = ($ 24,573 + $ 542) x 4 miles x 50 years x .90 % reduction / $ 1,400,000 + (75 x $ 500) = $4,520,700 / $ 1,425,000 = 3.172. The mitigation is expected to pay for itself over the 50 year time period it is expected to last, and in fact, the ratio is so high, it is predicted to pay off the cost in less than 16 years.

FHWA Values Benefit-Cost Equations

Benefit / Cost = ($ 43,488 + $ 542) x 4 miles x 50 years x .90 % reduction / $ 1,400,000 + (75 x $ 500). This equates to: $ 7,925,250 / $ 1,425,000 = 5.562 The mitigation is expected to more than pay for itself over 50 years it is expected to last. In fact, the mitigation is expected to pay for itself in less than nine years.

US 50 2016 Horse Fencing MM 17.4 - 20.4 and 26.15 – 29.30 Benefit-Cost Equation

US 50 2016 Horse Fencing Crashes MM 17.4 - 20.4 and 26.15 – 29.30

Pre-Construction 2007-2015 - MM 17.4-20.4 = 8 crashes, 2 B injury, 3 C injury, 3 PDO all with horses: MM 26.15-29.3 = 6 crashes, all PDO

US 50 2016 Horse Fencing MM 17.5-20.3 and MM 26.25 – 29.20, Pre-Construction 2006-2014 Carcasses: Section MM 17-20 = 4 Deer, 5 horses. Section MM 26-29 = 1 deer, and 1 dog, 1 coyote.

NDOT Values Benefit-Cost Equations

Benefit / cost = ($ 9,811 + $ 97) x 5.75 miles x 50 years x 90 % reduction / $ 750,000 + (50 x $500). This equates to: $ 2,563,695 / $ 775,000 = 3.308 The mitigation is expected to pay for itself over the 50 years it is expected to last, and can even be expected to pay for itself in just over 15 years.

FHWA Values for Crashes

Benefit / Cost = ($ 17,022 + $ 97) x 5.75 miles x 50 years x 90 % reduction / $ 750,000 + (50 x $500). This equates to: $ 4,429,541/$ 775,000 = 5.715 The mitigation is expected to pay for itself over the 50 years it is expected to last, and in fact is expected to pay for itself in less than nine years.

USA Highway, SR 439 Benefit Cost Equation

There are no historic crashes or carcasses because this is a new road. If the mitigation cost $ 2,876,000 and is expected to last 75 years, it will need to prevent $ 38,347 worth of crashes annually, on average. That would equate to 3.75 PDO crashes annually throughout the mitigation 15.5 mile stretch on average. This would average 0.242 prevented crashes per mile per year. Considering that the number one horse hotspot is at the north end of the highway and averages 0.526 crashes per mile per year, and the number two horse hotspot is just south of the road, and averages 0.493 horse crashes per mile per year, it is very feasible this mitigation will pay for itself over the 75 years of time.

Discussion

Benefit-cost analyses are informative but are only a part of the overall evaluation of potential and existing mitigation. The costs assigned to the different crash types are the major factor in determining if mitigation projects can be expected pay for themselves over the years. The injury crash values and the FHWA values for those and the fatal crashes can create a positive benefit-cost value over 1 far faster than PDO type crash values, and NDOT crash values. The benefit-cost analysis used in this research was as simple as possible, it did not include discount rates or wide variations in crash and carcass values, although these were used in early iterations of the equations and analyses. The benefit-cost analyses are sensitive to values placed on crashes, length of time the mitigation is expected to last, and the percentage reduction in animal-vehicle collisions over time.

The values for crashes and carcasses are gross estimates of the societal value of crashes, and wild animals. Several trends were demonstrated in the benefit-cost analyses.

- The FHWA values for crashes other than PDO are from 75 percent higher to over twice as much as NDOT crash values. This creates benefit-cost ratios with higher values than NDOT, thus the cost-effectiveness value of a mitigation project can be much higher using these values.
- FHWA and NDOT values for more severe crashes with injuries increase the value of prevented crashes (the benefits) more greatly than the multiple PDO type crashes. In the example from the US 93 Ten Mile Summit, calculations demonstrate how a single Type C plus a single Type A crash could bring the value of crashes much higher than

dozens of PDO crashes, thus creating a greater value to the mitigation benefits. The Ten Mile Summit value of crashes per year per mile was $25,225 for NDOT values, a value far higher than any the segments of roads analyzed on US 93, I-80, and US 6.

- Horses and cattle cause more severe crashes, which would be expected from their body size. Mitigation projects that address horse-vehicle collision hotspots will almost certainly pay off over time in the reduction of these often injurious crashes due to the high values placed on injury crashes.

This analysis was meant to assist in the evaluation of several different existing and potential projects. The methods can be used on other potential projects as part of an overall evaluation of the worth of mitigation to Nevada, and should not be used as a sole predictor.

Recommendations

Future Benefit-Cost Analyses Should be Conducted with Caution

It would be helpful to vary the crash cost values from NDOT to FHWA values in predicting if a project will pay for itself in reduced crashes. It is also helpful to vary the number of years a mitigation project is expected to last, and the percentage decreases in crashes. These analyses should be seen as part of an overall evaluation of cost-effectiveness of structures and fencing.

NDOT Maintenance Should Make Consistent Efforts to Collect and Report Carcass Data

The benefit-cost analysis is only as robust at the data it is dependent on. Areas of the state cannot be compared among one another with different levels of caraccas reporting. Changes over time cannot be gauged with spotty reporting. Wildlife mitigation efforts will not come as close to a beneficial ratio that helps support the construction of additional wildlife mitigation as those efforts would with robust carcass data. If carcass data reporting does not improve in Nevada, it weakens the use of benefit-cost analysis for any type of planning or performance measures.

Update Crash Values Each Year

As NDOT and FHWA update crash values in the coming years, these values should be used in these calculations.

Future Updates to This Benefit-Cost Analysis

If NDOT would like to update these equations to make them more complex and thus more representative of costs and benefits, a NDOT reviewer of this report suggested using a three percent discount rate.

CHAPTER 5 GIS FILES ON ANIMAL-VEHICLE PRIORITY ROAD SEGMENTS TO ACCESS DURING EARLY TRANSPORTATION PLANNING

Introduction

The results of this research were documented in this report, and in geo-referenced files. These files were delivered to NDOT through electronic uploads to the NDOT server.

Methods

The methods used to secure and create these files are documented in Appendices A and E, and a guidebook available with the georeferenced folders, titled, 'Guidebook for creating priority hotspot maps based on NDOT crash data July 2018.'

Results

GIS maps, shape files, data Excel spreadsheets will be available to NDOT personnel. These data and maps will be housed on the NDOT Network through the NDOT GIS Services, within the IT Division. Folders contain geospatial data that pertain to the Nevada Prioritization of Wildlife-Vehicle Conflict in Nevada project completed June 2018.

Direct questions to:
Dr. Patricia Cramer
cramerwildlife@gmail.com

All GIS data was conducted using Esri ArcGIS 10.6.1. Map projects back-saved to version 10.4 to facilitate compatibility.
All data rights belong to the Nevada Department of Transportation.
All data were current as of June 2018. This included 2016 crash and carcass data and other NDOT related data layers.

Most spatial data were in the following spatial projection:
Universal Transvers Mercator (UTM)
Zone 11N, Meters
North American Datum of 1983
Data from other sources may have differing projections. Check file properties for more information.

FILE STRUCTURE in electronic database:

- AA_ReadMeDocs
  - ReadMe.docx
  - GUIDEBOOK FOR CREATING PRIORITY HOTSPOT MAPS BASED ON CRASH DATA JULY 2018.docx

- CustomPythonCode
    - PythonCodeReadMe.txt
    - CODE
- MapProjects
    - Bear_20170703.mxd
    - Bear_ArcMap10_4.mxd
    - Bighorn_Sheep_20170703.mxd
    - Bighorn_Sheep_20170703_ArcMap10_4.mxd
    - Burro_ 20170703.mxd
    - Burro_ 20170703_ArcMap10_4.mxd
    - Cattle_20170703.mxd
    - Cattle_20170703_ArcMap10_4.mxd
    - Coyote_Dog_20170703.mxd
    - Coyote_Dog_20170703_ArcMap10_4.mxd
    - Deer_20170703.mxd
    - Deer_20170703_ArcMap10_4.mxd
    - Elk_20170703.mxd
    - Elk_20170703_ArcMap10_4.mxd
    - Horse_20170703.mxd
    - Horse_20170703_ArcMap10_4.mxd
    - NV_Cattle_Vehicle_CollisionTop25_Hotspots.mxd
        - Nevada Top 25 Cattle Vehicle Collision Hotspots
    - NV_Cattle_Vehicle_CollisionTop25_Hotspots_ArcMap10_4.mxd
        - Nevada Top 25 Cattle Vehicle Collision Hotspots saved for ArcMap 10.4
    - NV_CumulativeEcologicalMap.mxd
        - Statewide ecological analysis
    - NV_CumulativeEcologicalMap_ArcMap_10_4.mxd
        - Statewide ecological analysis saved for ArcMap 10.4
    - NV_CumulativeSafetyEcologicalMap.mxd
        - Statewide cumulative safety and ecological analysis
    - NV_CumulativeSafetyEcologicalMap_ArcMap10_4.mxd
        - Statewide cumulative safety and ecological analysis saved for ArcMap 10.4
    - NV_CumulativeSafetyMap.mxd
        - Statewide cumulative safety analysis
    - NV_CumulativeSafetyMap_ArcMap10_4.mxd
        - Statewide cumulative safety analysis saved for ArcMap 10.4
    - NV_FatalRunOffRoad_2007_2016.mxd
        - Fatal Run off Road and top hot spots
    - NV_FataRunOffRoad_2007_2016_ArcGIS10_4.mxd

        - Fatal Run off Road and top hot spots (Saved for ArcMap 10.4)
    - NV_Horse_Vehicle_CollisionTop25_Hotspots.mxd
        - Nevada Top 25 Horse Vehicle Collision Hotspots
    - NV_Horse_Vehicle_CollisionTop25_Hotspots_ArcGIS10_4.mxd
        - Nevada Top 25 Horse Vehicle Collision Hotspots saved for ArcMap 10.4
    - NV_OptimizedGetisOrdHotSpotAnalysis_Example.mxd
        - Sample project for running the Optimized Hot Spot Analysis (Getis-Ord) using 2007 – 2016 Nevada animal-related crash data and buffers produced using the custom Python code
    - NV_OptimizedGetisOrdHotSpotAnalysis_Example_ArcGIS10_4.mxd
        - Sample project for running the Optimized Hot Spot Analysis (Getis-Ord) using 2007 – 2016 Nevada animal-related crash data and buffers produced using the custom Python code, saved for ArcMap 10.4
    - NV_Top25_AllAnimalRelated_Hotspots.mxd
        - Master all-animal-related statewide top 25 hotspot map
    - NV_Top25_AllAnimalRelated_Hotspots_ArcMap10_4.mxd
        - Master all-animal-related statewide top 25 hotspot map saved for ArcMap 10.4
    - NV_TopHotSpotsGT2miles_District1.mxd
        - District I Hotspots
    - NV_TopHotSpotsGT2miles_District1_ArcMap10_4.mxd
        - District I Hotspots (Saved for ArcMap 10.4)
    - NV_TopHotSpotsGT2miles_District2.mxd
        - District II Hotspots
    - NV_TopHotSpotsGT2miles_District2_ArcMap10_4.mxd
        - District II Hotspots (Saved for ArcMap 10.4)
    - NV_TopHotSpotsGT2miles_District3.mxd
        - District III Hotspots
    - NV_TopHotSpotsGT2miles_District3_ArcMap10_4.mxd
        - District III Hotspots (Saved for ArcMap 10.4)
    - NV_TopHotSpotsLT2miles.mxd
        - Nevada top 25 hotspots less than 2 miles in length
    - NV_TopHotSpotsLT2miles_ArcGIS10_4.mxd
        - Nevada top 25 hotspots less than 2 miles in length saved for ArcMap 10.4
    - NV_WVC_CrashHotspots_NoHCB.mxd
        - Wildlife-vehicle collision hotspots generated with horses, cattle, or burros
    - NV_WVC_CrashHotspots_NoHCB_ArcMap10_4.mxd
        - Wildlife-vehicle collision hotspots generated with horses, cattle, or burros saved for ArcMap 10.4
    - Pronghorn_20170703.mxd
    - Pronghorn_20170703_ArcMap10_4.mxd

- SpatialData
    - CommonData
        - Admin
            - Admin_Boundaries
                - NV_Data
                    - Land_Ownership
                        - NV_Land_Ownership_shp
                    - NDOT_Districts
                        - NDOT_District1.shp
                        - NDOT_District2.shp
                        - NDOT_District3.shp
                        - NDOT_District1_NV_Erase.shp
                            - For cartography
                        - NDOT_District2_NV_Erase.shp
                            - For cartography
                        - NDOT_District3_NV_Erase.shp
                            - For cartography
                    - NDOTCityLimits
                        - CityLimits.shp
                    - Roads
                        - NV_Roads_100k_shp.shp
                    - State_County_Boundaries
                        - NV_County_Boundaries_shp.shp
                        - NV_State_Boundary_shp.shp
                - USCB_Data (US Census Bureau)
        - Basemap_Data
            - Admin_Forests
                - S-USA.AdministrativeForest
                    - AdministrativeForest.shp (WGS84)
                    - USFS_utm11n.shp (USFS UTM)
                    - USFS_utm11n_NV.shp (Nevada Only)
            - DEM
                - Mosaics
                - mosaic_utm11n.img (DEM)
                - mosaic_utm11n_hill.img (Hillshade)
            - Lakes_Playas
                - lake_100
                    - lake_100.shp
                    - major_playa_utm11n.shp
                    - major_water_bodies_utm11n.shp

        - USCB_Places
            - tl_2016_32_place
                - major_places_utm11n.shp
                - major_places_utm11n_points.shp
                - major_places_utm11n_points_subset.shp
                - major_places_utm11n_points_subset1.shp
        - Nevada_Erase.shp (Erase area for cartography)
        - Nevada_Extent.shp (Extent area for cartography)
    - Road_Data
        - AADT (From NDOT)
            - AADT.txt
            - AADT_Segments.shp
            - Helpfile.pdf
            - Permanent_Stations.shp
            - Routes.shp
            - Short_Term_Stations.shp
        - NDOT_Roads2017
            - NDOTRoads.gdb (geodatabase from NDOT)
            - NDOTRoads.shp (Used for 2018 analysis)
        - Roads_May2015 (From NDOT)
            - NV_ROADS.gdb (Used for 2017 analysis prior to NDOT delivery of 2017 roads data above)
        - Roads_TRINA (From NDOT – October 2016)
            - TRINA_lines.shp
            - TRINA_points.shp
        - NV_MILEPOST_MARKERS.gdb
    - Wildlife_Data
        - Crossings (From NDOT April 2017)
            - NVWildlifeCrossings.gdb
        - Distribution (From NDOW March 2017)
            - NDOW_BighornSheep_Distribution2016
            - NDOW_BighornSheep_MovementCorridors_2010
            - NDOW_BlackBear_Distribution_2009
            - NDOW_Elk_Distribution_2013
            - NDOW_FishableLakes_2015
            - NDOW_MuleDeer_Distribution_2014
            - NDOW_PronghornAntelope_Distribution_2010
            - NDOW_Regions_2014
            - GSG_LocalWorkingGroupUnits_2010.zip
            - GSG_PopulationManagementUnits_2012.zip

    - Other ZIP files with data provided by NDOW, but not used in this project
- Mitigation (From NDOT May 2017)
    - NVWildlifeMitigation.gdb
- Vehicle_Conflicts
    - Extracted_Data
        - Carcass_Bear.shp
        - Carcass_Bighorn_Sheep.shp
        - Carcass_Burro.shp
        - Carcass_Cattle.shp
        - Carcass_Coyote_Dog.shp
        - Carcass_Deer.shp
        - Carcass_Elk.shp
        - Carcass_Horse.shp
        - Carcass_Pronghorn_Antelope.shp
        - Crash_Bear.shp
        - Crash_Bighorn_Sheep.shp
        - Crash_Burro.shp
        - Crash_Cattle.shp
        - Crash_Coyote_Dog.shp
        - Crash_Deer.shp
        - Crash_Elk.shp
        - Crash_Horse.shp
        - Crash_Pronghonr_Antelope.shp
        - Crashes_All_5110.shp
        - NV_AnimalRealted_2007_2016_NoHBC.shp (No Horse, Burrow, Cattle)
        - NV_AnimalRelated_Fatal_2007_2016.shp
        - WVC_Bear.shp
        - WVC_Bighorn_Sheep.shp
        - WVC_Burro.shp
        - WVC_Cattle.shp
        - WVC_Coyote_Dog.shp
        - WVC_Deer.shp
        - WVC_Elk.shp
        - WVC_Proghorn_Antelope.shp
    - Summary_Tables
        - WVCbyCounty.dbf
        - WVCbyRegion.shp
        - WVCbyYear.dbf

        - WildlifeData.gdb (from NDOT January 2017)
        - WildlifeDataShape (from NDOT January 2017)
- CrashData
    - NV_2007_2016_Fatal_RolloversRunOffRoad
        - Fatal rollover and run-off-road data extracted from NV crash database
    - 2016CrashData.zip
        - 2016 Crash Data as Provided by NDOT
    - NV_2007_2016_AnimalRelatedCrashes.shp
        - Master animal related crash file data used for hotspot analysis
- GetisOrdData (Contains raw data used for Getis Ord Hotspot Analysis)
    - GetisOrdAnalysisOutput_Example.txt
        - Optimized Hot Spot Analysis in ArcGIS produces a summary report of the Getis Ord process. This is a working example of that ouput
    - NV_GetisOrd_Simplified_Road_Segment_Buffers_05mile.shp
    - NV_GetisOrd_Simplified_Road_Segments_05mile.shp
    - NV_OptimizedGetisOrd_RawOutput.shp
        - Initial Optimized Hot Spot Analysis run on Nevada 2007 – 2016 Animal Related Crash data. This file serves as an example of the OHSA procedure
- HotSpotAnalysisData
    - AnalysisRoads
        - NV_2017_AnalysisRoadNetwork_GetisOrd_Simplified.shp
            - Network used for GetisOrd analysis (2017 supplied by NDOT)
    - ByDistrict
        - NDOT_District_1_TopHS_GT_2mi.shp
            - Mapped hotspots greater than 2 miles in length (District I)
        - NDOT_District_2_TopHS_GT_2mi.shp
            - Mapped hotspots greater than 2 miles in length (District II)
        - NDOT_District_3_TopHS_GT_2mi.shp
            - Mapped hotspots greater than 2 miles in length (District III)
    - StateHotSpots
        - NV_ARC_Hotspots_LargerThan2milesPointsTop25.shp
            - Statewide Nevada animal-related mapped hotspots greater than 2 miles in length
        - NV_ARC_Hotspots_LargerThan2milesPointsTop25_NoHorseCowBurrow.shp

        - Nevada animal-related hotspots greater than 2 miles in length calculated without horse, cattle, and burrow incidents. Note this is different from the NV_ARC_Hotspots_LargerThan2milesPointsTop25.shp file
      - NV_ARC_Hotspots_SmallerThan2milesPointsTop25.shp
        - Nevada animal-related hotspots less than 2 miles in lenght
      - NV_CattleVehicleCollisionTop25Hotspots.shp
        - Nevada top 25 cattle-vehicle collision hotspots for 2007 - 2016
      - NV_HorseVehicleCollisionTop25Hotspots.shp
        - Nevada top 25 horse-vehicle collision hotspots for 2007 - 2016
  - SafetyEcologyData
    - NV_Cumulative_Ecological_Analysis.shp
      - Nevada Ecological Analysis (see final report for detailed information)
    - NV_Cumulative_Ecological_Safety_Analysis.shp
      - Nevada cumulative (combined) ecology and safety analysis (see final report for detailed information)
    - NV_Cumulative_Safety_Analysis.shp
      - Nevada Ecological Analysis (see final report for detailed information)
    - NV_Safety_Ecological_Top25_Points.shp
    - NV_Safety_Ecological_Top100_Points.shp

Recommendations

NDOT Develop a Standard Regular Process of to Update New Maps

The February 6th, 2018 meeting with NDOT GIS staff left the researchers a bit taken back by the fact that IT Services GIS specialists do not perform this type of work for NDOT Environmental Services staff. A member of the NDOT GIS staff expected environmental services staff to take a course or two on GIS to get up to speed to conduct these analyses. The PI, Dr. Cramer strongly advises NDOT to develop a regular process of producing these maps in house with trained GIS professionals, or to create a process which outside consultants can follow the final instructions the researchers provide. Environmental staff should not be expected to re-create these maps in ArcGIS.

CHAPTER 6 A FRAMEWORK WITH STANDARD MEASURES TO USE AS BENCHMARKS TO TRIGGER THE NEED FOR ANIMAL ROAD CROSSING MITIGATION

Introduction

There are two kinds of data NDOT personnel should consider when planning projects and evaluating existing roads to determine the need for animal-road crossing structures: highway safety data and ecological data. The work in this report largely brings these data and maps together. This task presents potential benchmarks for when mitigation is necessary, based on individual data types, or several taken in tandem.

Highway Safety Data

Average Annual Daily Traffic (AADT)

Traffic forms a barrier to animal movement. Different animals have different responses to traffic (Jacobson et al. 2016). In this study the researchers used three thresholds for AADT, which are related to the chance of mortality of animals as they try to cross roads with these various levels of traffic. At AADT values less than 2,000 vehicles per day, there is still some permeability for animals to cross the roads during low traffic times, mainly at night. Smaller animals are still highly challenged by these traffic levels. If the smaller animals are reptiles or amphibians, night movement is not an option, since these cold blooded species cannot move at night. When species are small such as desert tortoises, and move only during daytime hours, as much as 10 vehicles per day can prove too risky for successful crossing (Jacobson et al. 2016). When AADT is 2,000 vehicles per day, this typically becomes the beginning of a need for structures and fencing for larger ungulates. Herds of animals like elk, slow moving animals like smaller mammals and reptiles, and evader type animals like jack rabbits have lower success rates for crossing a road when levels rise above 2,000 AADT.

The AADT of 10,000 vehicles per day is the upper limit for animals to be able to cross roads and populations to survive on both sides of the road; over 10,000 vehicles per day, the animals have a far greater chance of members of a herd becoming a hazard to traveling public. Ten-thousand vehicles per day forms a near complete barrier (Charry and Jones 2009). The ranking of AADT is based on literature (Charry and Jones 2009) and the hotspot modeling in this research. The cumulative Safety and Ecological Wildlife-Vehicle Conflict map was created by ranking AADT in three classes. The AADT of greatest concern thus given the highest scores were those roads with $\geq$ 10,0000 AADT. The second tier ranking was for roads with AADT = 2,001 to 9,999. Lowest scores for AADT ranking were for roads below 2,000.

Crash Data

Animal-Vehicle Collision Crashes per Mile

Transportation planners and others in NDOT must strongly evaluate wildlife mitigation options when the number of animal-vehicle collision reported crashes average 0.65 crashes per mile per year and higher. The top 25 animal-vehicle collision crash hotspots mapped in this study had values of 0.65 crashes per mile per year and higher. These values equate to the worst animal-related crashes in the state.

Severity of Crashes

If there are any human injury or fatality animal-related crashes in the segment of road under consideration, this would be the main threshold to raise the level of importance of this stretch of road for animal mitigation. Larger bodied animals such as horses and cattle cause a greater proportion of their crashes to become injury and death related for the motorists involved, and thus pose the highest safety hazard for the motoring public. These areas are predicted to continue to pose risk if no actions are taken.

Percentage of Crashes Animal-Related

In this research, the average percentage of total statewide crashes that were animal related was 2.4. If a stretch of road has a percentage crashes that are animal-related of greater than 2.4 percent, it is time to examine other animal-related factors. If the road under examination has 2.4 to 10.6 percent of crashes involving animals, there is a problem with animals on the road. If the percent of animal-related crashes is greater than 10.6 percent, the road is among the top problem areas in the state and mitigation is necessary.

Carcass Data

If the carcass data analysis reveals 0.10 to 0.99 carcasses per mile per year, there is a potential animal-vehicle collision problem. If the carcass numbers are greater than 1 per mile per year, then there is high probability the segment of road is among the top 25 hotspot priority areas. These numbers were taken from the carcass data supplied from NDOT for this study.

Number of Lanes

Roads greater than 2 lanes in width make it difficult for wildlife and livestock to cross safely. The greater number of lanes, the more need for wildlife and livestock crossing structures. The number of lanes in a hotspot area for animal mitigation can limit options. If the road is two lanes, most options are available. If the road is greater than two lanes, then animal detection systems and driver warning systems are not an option, see below.

Mitigation options that involve driver warning devices connected with animal detection systems can only be placed on two lane roads. These roads also have to have a speed limit of 55 miles per hour (mph) or less in order for motorists to slow down to avoid collisions with animals. The mitigation segment of road must be measured in hundreds of feet where animals are detected and no greater, until such systems prove they are capable of warning motorists over distances of miles or more. Note: technology is being developed and this limited length is expected to increase. For example, in British Columbia, there is an animal detection system based on thermal cameras and radar that warns motorists of wildlife on Highway 3, over 5.6 miles, that is believed to work well in reducing collisions (Sielecki 2017).

Ecological Data

Species' Presence

There are three types of data on wildlife species' presence that could be considered in transportation planning: protected species locations, wildlife habitat and corridor maps, and empirical data on collared animal locations.

Locations of Protected Species

It is immediately time to consider wildlife mitigation and consult with wildlife professionals if protected species, such as species state and federally listed as threatened and endangered are present near a stretch of road, or are expected to use the area. This includes re-introduced endangered and threatened species. NDOT personnel will need to contact U.S. Fish and Wildlife Service representatives for maps of potential habitat, and mitigation options and requirements. If the U.S. Fish and Wildlife Service has concerns about protected species near a road project or a new road, there will be conversations on potential wildlife crossing mitigation.

Wildlife Habitat and Migration Corridors

NDOW mapped habitat and migration corridors for mule deer, elk, mountain goats, bighorn sheep, pronghorn, and black bear and are available from NDOW. NDOW maps of certain species' corridors and habitat are available to view the probable presence of these species across the state. If the road project is within these areas, NDOW should be involved in planning. There may be updated materials available in the coming years for these ungulate habitat and corridor identified sites.

Collar Locational Data

NDOW has GPS collars on dozens to hundreds of animals at any given time. Maps of the data are available from NDOW for including consideration in road planning. NDOW generated a map for this study that is available to NDOT personnel. It shows the locations of all collared large mammals within one mile of every NDOT administered road, see Figure 46 below. As additional data become available, NDOT should contact NDOW colleagues for updated maps.

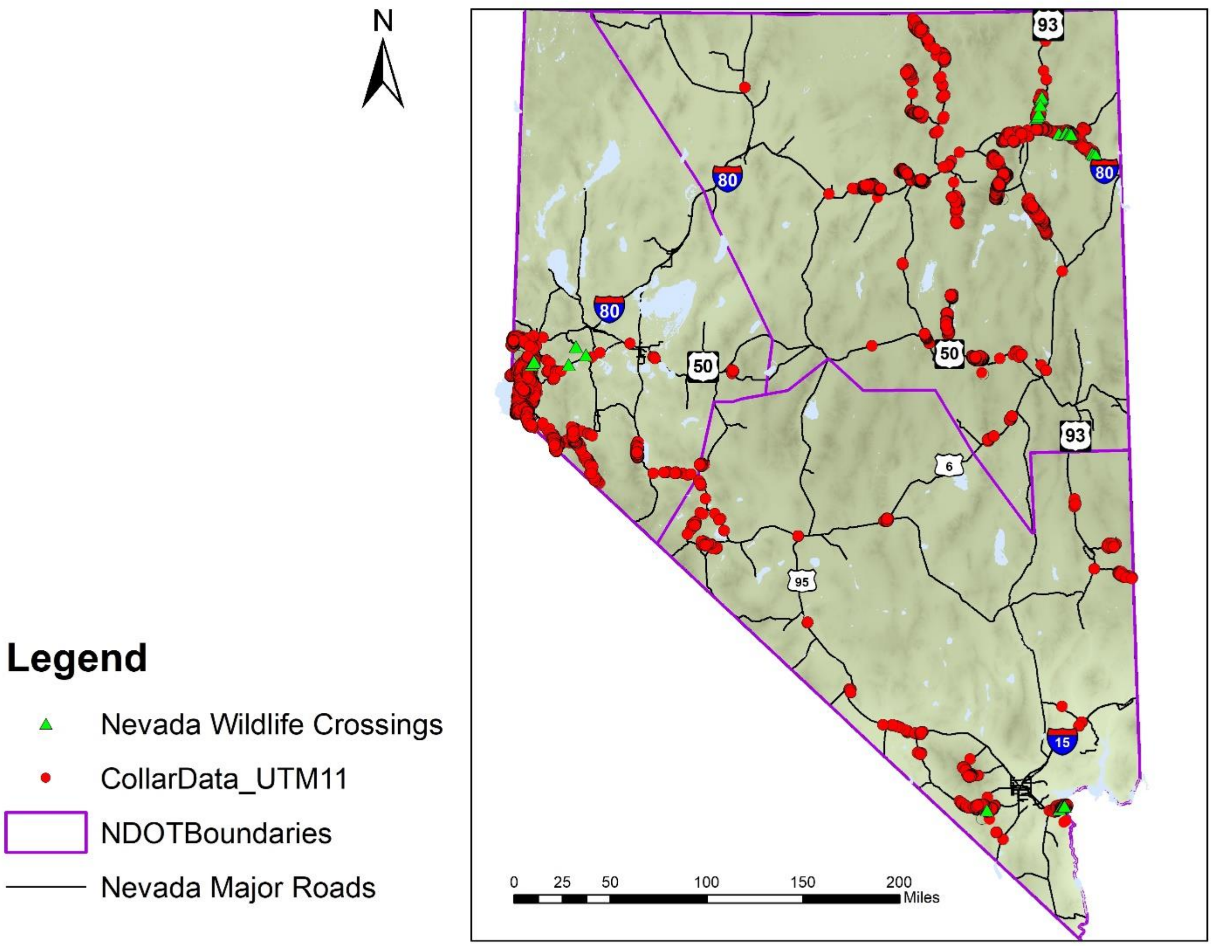


Figure 46. Collar Locational Data for Mule Deer, Elk, Bighorn Sheep, Pronghorn Antelope, Black Bear, and Puma, Buffered For Locations Within One Mile of All NDOT Roads and Highways, Developed by Nevada Department of Wildlife 2017.

Water Features

Transportation planning should consider riparian areas. If there are water bodies within 1/10th of a mile of a road or project, planners should refer to wildlife and livestock crash and carcass data to evaluate how often animals have been involved in crashes in the past. In Nevada these areas attract wildlife and crash and carcass data display patterns of increased numbers of animals killed along these important resources. If a road under consideration for planning or annual evaluation is near a water body, the crash and carcass data, turtle and amphibian data, and other information about species' presence should be reviewed. A new wildlife crossing structure may not be necessary, but a review of existing culverts and bridges and their ability to pass target species would be a place to start for environmental staff. The Passage Assessment System (PAS, Kintsch and Cramer 2011) is a standardize score card for evaluating culverts, bridges, and fencing for their potential to be retrofit for different species' groups.

In conjunction with referencing existing data, transportation planning can be guided by the simple questions presented in Figure 47, below. If mitigation for animal-related conflict is deemed a potential or necessary action, Table 45 presents options that target drivers and wildlife, the difficulty in time and effort to deployment, effectiveness, use across the U.S, and cost. Nevada has become well versed in creating wildlife mitigation, and it would be of use to provide wildlife crossing structure, fencing, escape ramps, and double cattle guard plans, cost estimates, photos and reports of how well mitigation worked in a central electronic location for NDOT employee access.

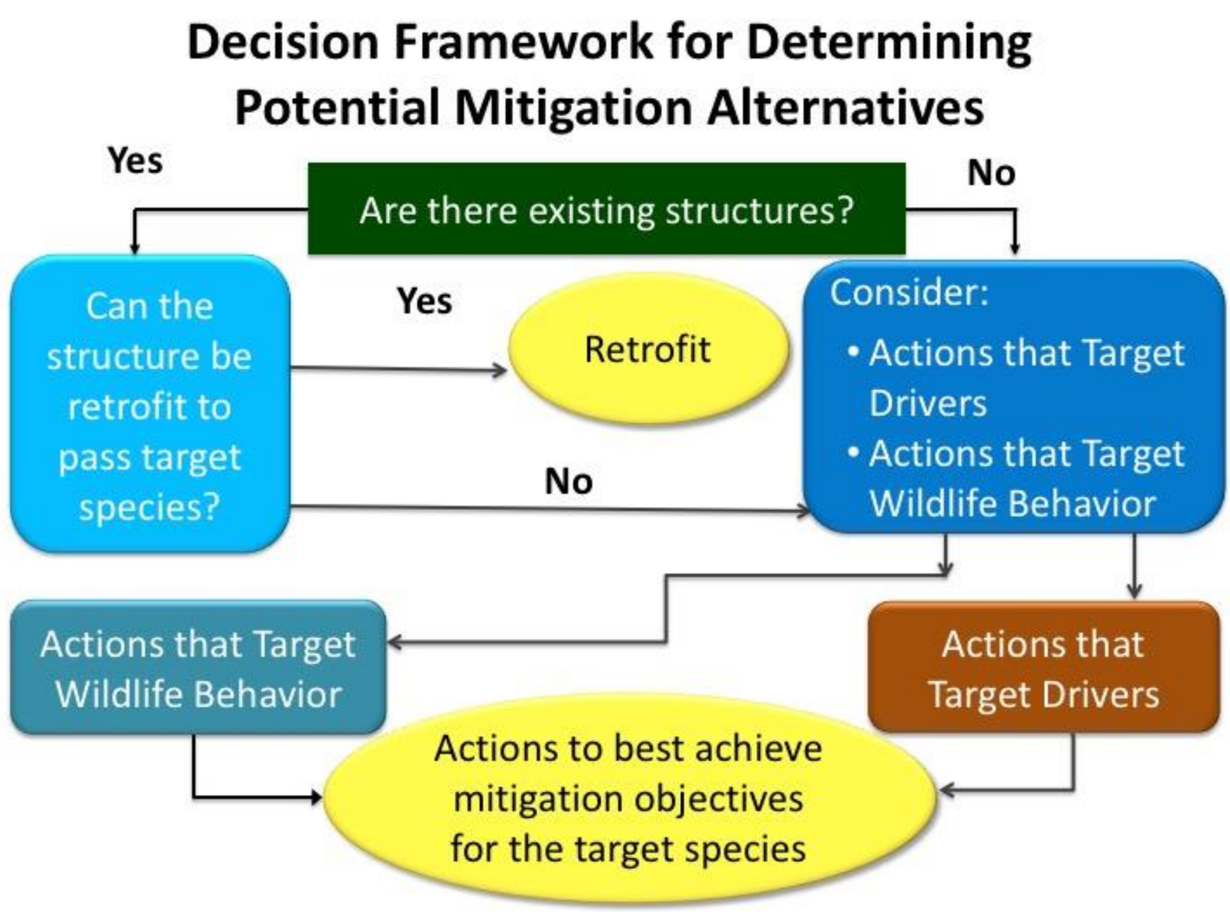


Figure 47. Decision Framework for Selecting Wildlife Mitigation. Taken from Cramer et al. 2016 report to South Dakota Department of Transportation.

Table 45. Mitigation Options to Reduce Conflict with Wildlife on Highways. Adapted from Cramer et al. 2014, 2016.

Measure	Difficulty in Effort and Time to Deployment	Effectiveness	Use Across the U.S.	Cost
1. Actions that Target Wildlife				
1.a. Assess Infrastructure for Retrofits				
Use the Passage Assessment System (Kintsch and Crame 2011) for evaluating existing structures and fencing for changes that could benefit wildlife	Low	Medium	Medium	Low
1.b. Detract Roadside Value for Wildlife				
Supplemental feeding away from road to draw animals from road	Low	Unknown	Low	Low
Vegetation Management	Low	Low-Medium	Medium & Unknown	Low
1.c. Deter Wildlife from Roadway				
Wildlife deterrent devices mounted on roadside posts that produce noise & reflect light	Medium	Low	Low	Medium
Reflectors, Whistles	Low	Low	High	Low
1.d. Exclude Wildlife from Road and Provide Below- or Above-Grade Crossings				
Fencing	Low	Medium to High	High	Medium
Only Wildlife fencing with double cattle guards & escape ramps – no structures	Medium	High	High	Medium to High
Wildlife crossing structures with wildlife fencing, escape ramps & guards	High	High	High	High
1.e. Reduce Wildlife Populations				
Sharpshooting deer in suburban areas to reduce population	Low-Medium	Medium-High	Medium	Low
2. Actions that Target Drivers				

Measure	Difficulty in Effort and Time to Deployment	Effectiveness	Use Across the U.S.	Cost
2.a. Public Education and Awareness				
Public awareness campaigns	Medium	Largely Unknown	High	Low
2.b. Signage				
Static driver warning signs	Low	Low	High	Low
Variable message boards	Low	Low-Medium	High	Low
2.c. Speed Reduction				
Wildlife crossing zones with reduced motorist speed limit	Low	Low-Medium	Low	Low
2.d. Driver Warning Systems				
Thermographic cameras to detect wildlife on or near road– used in vehicle or along road with driver warning system	High	Medium (Experimental)	Low	High, Future
Animal detection systems that use thermographic cameras with radar to detect wildlife and warn drivers of animals on road in real time	High	Low-Medium	Low	High
2.e. Road Treatments to Improve Driver Sight Lines				
Vegetation Management	Low	Low-Medium	Medium	Low
Roadway Lighting	High	Low-Medium	Low	Low

Summary

This chapter is a reference for how NDOT can guide transportation planning with simple numeric thresholds on commonly used data, and how the series of questions presented can be used to determine the need for animal mitigation. In future work, NDOT will need to establish these thresholds and guidance in operating procedure manuals for the various divisions and professions within NDOT at the headquarters and district levels.

CHAPTER 7 POTENTIAL SOURCES OF FUNDING FOR WILDLIFE CROSSING MEASURES

Introduction

Wildlife crossing structures and concurrent mitigation such as fences and escape ramps can be expensive additions to road projects. DOT's have become proactive in partnering with federal, state, and local agencies, non-profits, and citizens to fund wildlife mitigation projects. This chapter highlights funding resources from federal programs that have been used to fund wildlife crossing structures, to local governments, certain non-profit organizations, and examples of citizen initiatives to fund such projects. The chapter ends with three examples of how state DOT's used creative and diverse funding sources for wildlife crossing structures.

Methods

The researchers combined their knowledge and asked colleagues in western U.S. States how wildlife mitigation projects have been funded. The examples of successful partnership funding projects were taken from Utah, Montana, Colorado, California, and Arizona.

Results Funding Sources Used in Western States for Funding Wildlife Mitigation

Local Governments

Local governments are active partners with transportation projects and can provide soft and hard money matches. Soft money matches could be for necessary pre-construction surveys, or actual building of infrastructure, such as double cattle guards. Hard money are actual funds these entities bring to the project. In Colorado, the State Highway 9 wildlife crossings project (case study below) was highly supported by two counties, which were also involved in raising private and citizens funds.

State Wildlife Agencies

Wildlife agencies can provide direct funds to wildlife mitigation projects, or funds and human power through conservation group matching funds. For example, in Utah, the state wildlife agency, Utah Division of Wildlife Resources (UDWR) provides hunting licenses (tags) to the sportspeople groups such as Mule Deer Foundation and the Rocky Mountain Elk Foundation. In return, these foundations hold annual auctions for these tags, and share half the proceeds with the wildlife agency. The wildlife agency then can work with these groups to specify where these funds should be allocated. In Utah, transportation mitigation projects are a popular recipient for these proceeds. The sports people groups also give their own funds toward wildlife mitigation projects. The Mule Deer Foundation, Rocky Mountain Elk Foundation, and

Sportsmen for Fish and Wildlife have all written checks to state departments of transportation to help pay for fencing and wildlife crossing structures. In Nevada NDOW was able to secure a wildlife grant for construction of the I-80 wildlife overpass. These funds were from the U.S. Fish and Wildlife Service's Wildlife and Sport Fish Restoration Program. The monies are from Pittman Robertson dollars (U.S. Fish and Wildlife Service 2018a). Wildlife agencies can apply for federal grants through the Pittman Robertson's Act (US Fish and Wildlife Service 2018b). In Utah and Arizona, these funds helped fund research on wildlife crossings structures. In Nevada, these funds helped pay for wildlife mitigation on US 93 and I-80.

State Transportation Agency Use of Federal and State Funds

Transportation project needs, description, design, and delivery are all created and controlled by the state DOT, often in coordination with the FHWA. This typically applies only to roads administered by NDOT, and does not apply to local county, town, and neighborhood roads. Wildlife mitigation projects can be funded through resources from the federal government (FHWA) and from state funds. Individual states decide how to use their overall share of federal funds and how much to allocate to the planning and construction of wildlife crossing structures and fencing. State transportation dollars can be directly applied to wildlife mitigation projects. These are typically through the safety, maintenance, and environmental pots of money, and have also included transportation enhancement grants, which no longer exist.

State Traffic Safety funds have traditionally been the go-to funds for wildlife mitigation project that involved larger animals such as deer and elk. The state traffic safety engineer typically looks at historic crash data in an upcoming project area to make recommendations to reduce crashes and can perform a benefit-cost analysis of the proposed project's potential ability to reduce these crashes. Regional or district engineers have also conducted these crash analyses and benefit-cost analyses to help justify the use of traffic safety funds for wildlife mitigation. The safety approach is appropriate for highways where collisions with wild and domestic animals may comprise one-third or higher of all collisions. The Nevada Department of Public Safety-Office of Traffic Safety allocates federal funds for safety projects (Nevada State 2017) and could make the case that funds for projects could be used on projects that would be expected to decrease rates of serious injury and fatality from collisions with animals. If the project was in an area that frequently (every year or every other year) experienced high rates of injury/fatality accidents from collisions with, or avoidance of animals, then a case could be made for mitigation activities.

Federal Highway Safety Improvement Program (HSIP)

The goal of this program (Federal Highway Safety Improvement Program 2018) is to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-state-owned roads and roads on tribal lands. The program requires that in order to receive these funds the approach be data driven to use strategic approaches to improving highway safety with a focus on performance. There are three main components: the Strategic Highway Safety Plan (SHSP), State HISIP or program of highway safety improvement projects, and the Railway-Highway Crossing Program (RHCIP). States have used funds from this program to fund wildlife mitigation based on reducing the risk of wildlife-vehicle collision crashes and saving human lives and injuries.

Federal Tribal Transportation Programs (TTP)

The Tribal Transportation Program (Federal Tribal Transportation Program 2018) is the largest program within the Office of Federal Lands Highway. It is designed to address the needs of Tribal Governments to provide safe and adequate transportation and public road access to and within Indian reservations and Indian lands. Within this program (TTP), there is a Tribal Transportation Program Safety Funds program (TTPSF) (Tribal Transportation Safety Funds. 2018). Each year two percent of the TTP funds are set aside to address transportation safety issues in Native America. The funds are awarded annually through a competitive process.

Federal Nationally Significant Federal Lands and Tribal Projects (NSFLTP)

Fast Act Transportation Act (2015) established the Nationally Significant Federal Lands and Tribal Projects program (NSFLTP) (Federal Nationally Significant Federal Lands and Tribal Projects 2018) that provides funding for construction, reconstruction and rehabilitation of nationally significant projects on Federal or tribal lands. The eligible projects must have an estimated cost of at least 25 million dollars.

Federal Lands Transportation Program (FLTP) for Federal Lands

The FLTP funds projects that improve access within Federal Lands that include national parks and forests, wildlife refuges, recreation areas, and other federal public lands on transportation facilities in the National Federal Lands Transportation Inventory (Federal Lands Transportation Program 2018). With each transportation act, each federal agency is allocated a set amount per year. For example, the Transportation Fast Act allocated 15 – 19 million dollars per fiscal year for the U.S. Forest Service.

Federal Lands Access Program (FLAP)

FLAP or Access Program provides funds for projects on Federal Lands Access Transportation Facilities that are located in or adjacent to or that provide access to federal lands (Federal Lands Access Program 2018). These lands include those Federal lands managed by the National Park Service, the U.S. Forest Service, the U.S Fish and Wildlife Service, the Bureau of Land

Management, and the U.S. Army Corps of Engineers. Eighty percent of the of the funds go to states with at least 1.5 percent of the national total of public lands.

Federal Transportation Alternatives Program (TAP)

The FAST Act eliminated the MAP-21 Transportation Alternative Program (TAP) and replaced it with a set-aside of Surface Transportation Block Grant (STBG) program funding for transportation alternatives (TA) (Federal Transportation Alternatives Program 2018). These are set aside funds are for a variety of smaller scale transportation projects, including environmental mitigation related to habitat connectivity. This is a new category with the Fast Act.

Federal Transportation Investment Generating Economic Recovery (TIGER)

In 2017, there was nearly 500 million dollars available for this program, for transportation projects (Federal Transportation Investment Generating Economic Recovery 2018). This program is highly competitive, and supports innovative projects, which don't typically fit within the traditional federal funding programs. While workshop and conference participants speak of this source as a potential pot of money to help fund wildlife mitigation projects, the authors did not find evidence of its use in this manner.

Possible Solutions for Additional Funding

Creative funding mechanisms have been used and discussed to raise new revenue for funding wildlife mitigation. Citizens have voted to tax themselves (and voted down such initiatives) to fund wildlife overpasses and underpasses (see case studies below), created non-profit organizations to receive donations from citizens (see Colorado SH 9 case study below), and used large donation funds from private sources to contribute to wildlife mitigation projects (see SH 9 case study below). Creative ideas for funds that have been mentioned over the course of multiple gatherings of wildlife and transportation professionals include: local impact fees for developers; recreation user fees for the area; license plates for wildlife mitigation where proceeds go to wildlife projects, which just occurred in 2017 in Wyoming; options for private landowners in road widening projects with wildlife crossings to donate the land purchase payments back toward wildlife crossing structures' costs; and a state gas tax increase to help fund transportation needs that include those for wildlife.

Non-Profit Organizations

Organizations that focus on conservation, wildlife hunting, wildlife preservation, fish conservation, or cycling and recreation share the common goal of saving wildlife from being killed on the road, and a wildlife crossing structure and mitigation project could also serve their missions. In Utah on US 89, the Mule Deer Foundation and the Sportsmen for Fish and Wildlife contributed hundreds of thousands of dollars, signs, and personnel time to the Paunsaugunt US 89 Wildlife crossings project (see story below). The organization Muley Fanatics donated money toward the Colorado SH 9 wildlife mitigation research project. Non-profit organization can be established specifically to raise funds for wildlife crossing structures. In Colorado the non-profit Grand Foundation, a 501b3 non-profit organized prior to the wildlife mitigation on SH 9, to help improve life for Grand County citizens, took in citizens' and business' contributions to the SH 9 wildlife mitigation project (see story below).

Citizens' Organizations and Private Funding

Citizens can raise tens of thousands to millions of dollars for transportation mitigation projects. For instance, in Utah in 2016-2017, a citizens' group, Save People Save Wildlife, raised $50,000 in less than four months which they delivered to Utah Department of Transportation to pay for wildlife fencing to keep moose, mule deer, and elk off I-80 in the Jeremy Ranch area of the mountains east of Salt Lake City. In Colorado, citizens created a committee, Citizens for a Safe Highway 9, which had seven board members. They were the interface for citizen and business education and contributions for the project. This group helped raise millions of dollars in private contributions toward the wildlife mitigation project. See case story below for more details.

In 2010 in Collier County, Florida, a developer paid 1.3 million dollars to build a wildlife crossing structure under a county road to benefit the endangered Florida panther. This action was part of the mitigation required under a Habitat Conservation Plan associated with habitat take to develop a business park. More recently, private funders have been raising funds to help Caltrans build a ~50 million dollars structure across US 101 in Southern California to re-connect wildlife populations genetically separated by an essentially-impenetrable highway.

Case Studies of Collaborative Funding of Transportation Wildlife Mitigation Projects

US Highway 89 Kanab and the Paunsaugunt Mule Deer Herd

Figure 48. Mule Deer Wait to Move Through Wildlife Crossing Culvert Under US 89 East of Kanab, Utah.

US Highway 89 (US 89) east of Kanab, Utah bisects the seasonal migration of the Paunsaugunt mule deer (*Odocoileus hemionus*) herd. This herd lives near Bryce Canyon on the Paunsaugunt Plateau in southern Utah. The herd overall, travels south toward Arizona in the winter, and north toward Bryce Canyon National Park and Cedar Mountain in the summer. In 2013 Utah Department of Transportation (UDOT) and UDWR worked together with multiple partners to create the US 89 Kanab-Paunsaugunt Project. It stretches from mile post (MP) 36 to 48.6. The project includes 12 miles of wildlife exclusion fencing on both sides of the road, three existing culverts and a bridge, and three new wildlife crossing culverts, all in the Grand Staircase Escalante National Monument (Figure 48). The goal of the project was to funnel a portion the Paunsaugunt mule deer herd through the new wildlife crossing culverts and existing culverts and bridge to help reduce the mule deer-vehicle collisions in this area.

UDOT partnered with UDWR to find collaborative solutions to funding this mitigation. UDOT and UDWR sports people partners went before the UDOT transportation commission to stress the importance of the project in reducing mule deer-vehicle collisions. The commission directed that $ 625,000 of Transportation Enhancement Funds be allocated to the project if there was matching funding. Kane County committed in-kind contributions by installing all the double cattle guards for roads and driveways along the fencing. The Bureau of Land Management, managers of the Grand Staircase-Escalante National monument, obtained a Federal Highway Administration Public Lands grant for approximately 1.5 million dollars. The BLM also conducted all the anthropological surveys along the fence line. The Mule Deer Foundation donated $ 100,000 of funds generated from the auction of mule deer hunting tags to the project fencing. The Sportsmen for Fish and Wildlife organization had hunter members volunteer to walk the fence line to look for holes in the fence, and donated signs on all gates stating users should close the gates for wildlife. The Arizona Game and Fish Department donated $ 100,000 to the project, sent their biologists to help set up the monitoring cameras, and were part of the 5-year monitoring study. The partnership was so successful that UDOT and UDWR use this approach for the future wildlife mitigation projects across the state. UDWR habitat managers across the state are also finding ways to bring funds to transportation project to fund fencing, improve escape ramps, and adaptively manage existing infrastructure.

Montana Secondary Road 206 Wildlife Crossing Culvert

In 2007 Montana Department of Transportation (MDT) worked with local landowners on a slope flattening safety project on SR 206 when they learned that landowners were interested in a culvert to help move livestock and to allow wildlife to move safely beneath the road (Figure 49). Funding for his project came from many sources. MDT paid the landowners for the widened highway take of their land. In turn, that landowners returned the money to MDT to help pay for the wildlife crossing. Montana Fish, Wildlife, and Parks brought money to the project. Pat Basting, the MDT district biologist worked with the non-profit American Wildlands to interact with the public and other non-profits to raise the needed funds. Nonprofit organizations, including Yellowstone to Yukon, the Northern Rockies Conservation Cooperative, Friends of the Lower Swan, and two hunting and fishing organizations also donated money to the project. The Flathead county commissioners contributed money. A developer of a nearby housing development gave money. Local and distant individual members of the public also gave money for the crossing structure. The supporters attempted to write grant proposal to secure funding from larger foundations, such as the Doris Duke Foundation, but found the funding cycles for these organizations did not coincide with the short time line for the fund raising for this structure. The culvert was placed in 2014. It has been monitored by MDT environmental staff, and cameras documented mule deer and other wildlife using the structure.

Figure 49. Wildlife Crossing Culvert Near Kalispell, Montana on Secondary Road 206. *Photo Courtesy of Pat Basting*.

Colorado State Highway 9 Wildlife Crossings Public and Private Partnership

The State Highway 9 (SH 9) Colorado River South Wildlife and Safety Improvement Project was designed to improve driver safety while providing permeability for wildlife along a 10.4 mile stretch of the highway. Prior to the project, from 2007 – 2011, reported wildlife-vehicle collisions on this highway accounted for 35 percent of all reported crash types, making it the number one cause of crashes on this stretch of SH 9. While public acknowledgement of the problem was high, funding was a problem for Colorado DOT (CDOT) until the Blue Valley Ranch, located in the valley with this highway, donated $805,000 for design of new wildlife crossing structures and fencing. With this jump start of monies, citizens moved into action to build a coalition of partners and secure multiple funding sources for the project. Citizens for Safe Highway 9 (C49) was created as a non-profit with seven board members. They raised public funds for matching funds from Grand County and the Grand Foundation. This group was the lead for raising funds. A Memorandum of Understanding (MOU) was created with Citizens for Safe Highway 9 and Grand County and the Grand Foundation. The Grand Foundation is a charitable organization within the county to raise funds of all types of causes, for river restoration, school, etc. The Grand Foundation was the fiscal sponsor that handled the monies that came in. It is a 501c3 non-profit, so that donations were tax deductible charitable donations. They held the funds in escrow accounts, and monies were to be refunded if the project didn't make it. Seven local government entities donated 3.44 million dollars to the project, including three million dollars from Grand County, 250,000 dollars from Summit County, and 40,000 dollars from the nearby town of Kremmling. Thirty-five local businesses donated a total of 200,300 dollars. Private individuals (133) donated a total of 5,348,200 dollars, with donations ranging from 20 to two million dollars. Four environmental groups donated 216,000 dollars. There were 373 letters of support from local governments (11), local businesses (82), and citizens (280), clearly stating concerns about safety issues on the highway. In all there were 9,208,500 dollars raised outside of CDOT in support of the project. The Blue Valley Ranch donated five million dollars in total. The project cost over 46 million dollars, which resulted in seven wildlife crossings including two overpasses, eleven miles of fencing on both sides of the highway, and dozens of escape ramps, double cattle guards, and pedestrian gates, and a widened shoulder road. CDOT brought the remaining funds to the project, in part through Ramp Funding – Responsible Acceleration of Maintenance and Partnerships. This new program

Figure 50. Wildlife Crossing Overpass Official Ribbon Cutting Ceremony Near Silverthorne, Colorado on State Road 9.

helps CDOT to fund multi-year project based on the year of expenditure rather than saving for the full amount of the project before construction begins. RAMP funds are used on projects that show need for project, and tangible benefits. There should be a public-public partnership, such as was in this project between CDOT, CPW and the counties, the target for this funding is local contributions funds should cover 20 percent of the total transportation project cost (Figure 50). CDOT created a video explaining the project (Colorado Department of Transportation 2017). Summit County create a video filmed during the official ground breaking ceremony, which helps explain how the partnerships worked (Summit County 2017).

Taxation for Wildlife Mitigation

Several case studies are presented to explore the possibilities of funding through taxation.

The City of San Diego, California faced a backlog of transportation infrastructure repairs and construction that may have been as high as 1 billion dollars. In the short term, it has used general fund-backed lease-revenue bonds to fund smaller projects, but was unlikely to substantially reduce its shortfall with this approach (San Diego 2014). The county placed a sales tax measure (Measure A) on the 2016 ballot in an attempt to remedy this situation. It failed to reach the two-thirds majority required in California for new tax measures. Revenue from the 0.5 cent sales tax would have paid for transportation infrastructure, transit and open space projects. The city and county currently rely heavily on state and federal funds for the majority of new transportation projects. However, the absence of dedicated funding for wildlife movement in these sources meant that any improvements for wildlife will be part of existing projects. This San Diego example was included because Measure A would potentially have provided support for stand-alone wildlife projects across roadways.

The City of Boulder, Colorado had more success with the taxation approach, passing two separate 0.15 cent sales tax measures in 2013 that fund open space and transportation projects. The transportation funding is temporary until Boulder comes up with a more sustainable funding strategy. However, the combination of back-logged maintenance and community demands for multi-modal projects means that even this new source of funding is unlikely to solve looming shortfalls and currently there is no implemented plan to meet all needs. In addition, despite the progressive focus on transit and multi-modal travel in the Transportation Master Plan, 2014, there is no dedicated funding for facilitating wildlife movement, or other ecologically-oriented projects.

In 2006, Pima County, Arizona voters approved a regional transportation plan by the Regional Transportation Authority, and a one-half cent sales tax to fund the plan. In that 20 year plan, the Environmental and Economic Vitality funding category allocated 45 million dollars for wildlife linkage projects. The 45 million dollars cannot be used for any other purposes. The Oracle Road wildlife crossings project, which includes an overpass was built by Arizona Department of Transportation using the Regional Transportation Authority funding (Coalition for Sonoran Desert Protection 2018 and Arizona Game and Fish 2017)

CHAPTER 8 PRIORITIZATION AND IMPLEMENTATION PLAN

Introduction

This chapter identifies needs and sets priorities for implementing the results of this study.

The prioritization and implementation plan is based on three major steps:

1. Identify wildlife-livestock-vehicle conflict priority areas;
2. Integrate wildlife considerations into transportation planning; and
3. During and after project development - build, monitor and adaptively manage wildlife mitigation.

This plan includes actions both NDOT and NDOW will need to enact to implement the results of this research. Figure 51 presents an overview of these actions in blue boxes, with pink boxes representing NDOT actions, and green boxes representing NDOW actions. Each of the three major steps is further detailed below.

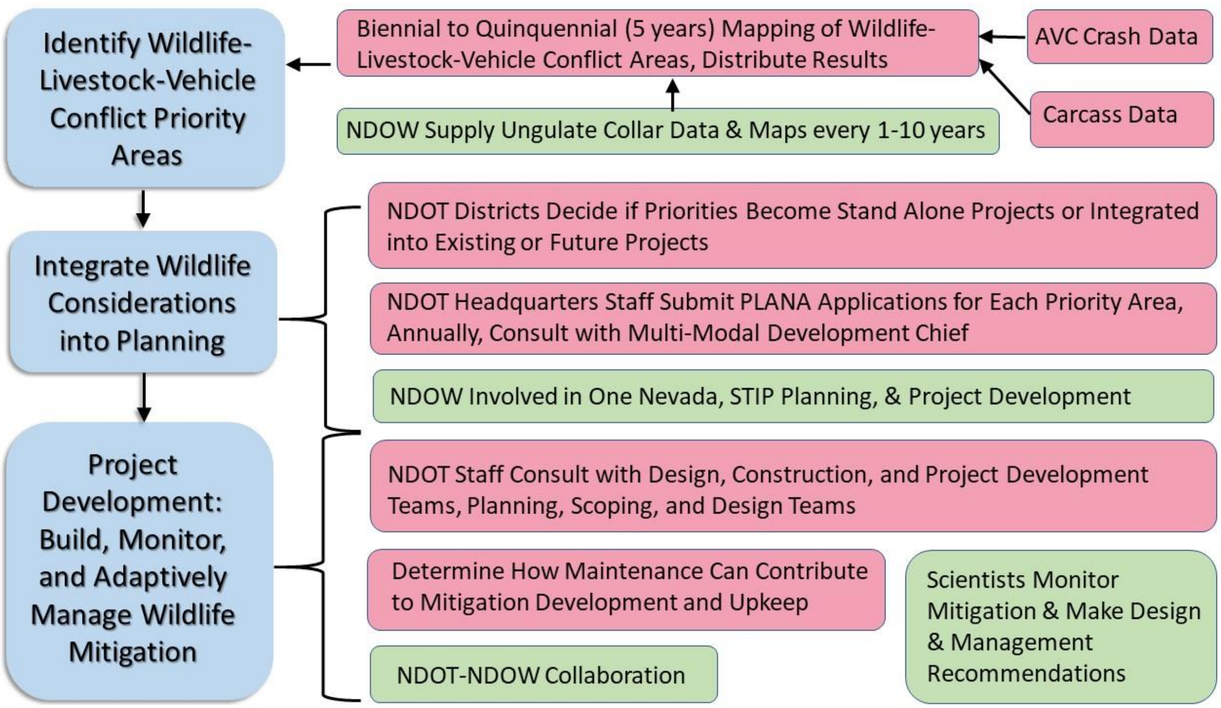


Figure 51. The Three Major Steps for Mitigating Roads for Animal-Vehicle Conflict and the Information and Actions That Support Each Step.
Pink Boxes Represent NDOT Actions, and Green Boxes Represent NDOW Actions. Figure adapted from Cramer et al. 2016.

The figure above is further refined within the context of NDOT planning, below in Figure 52.

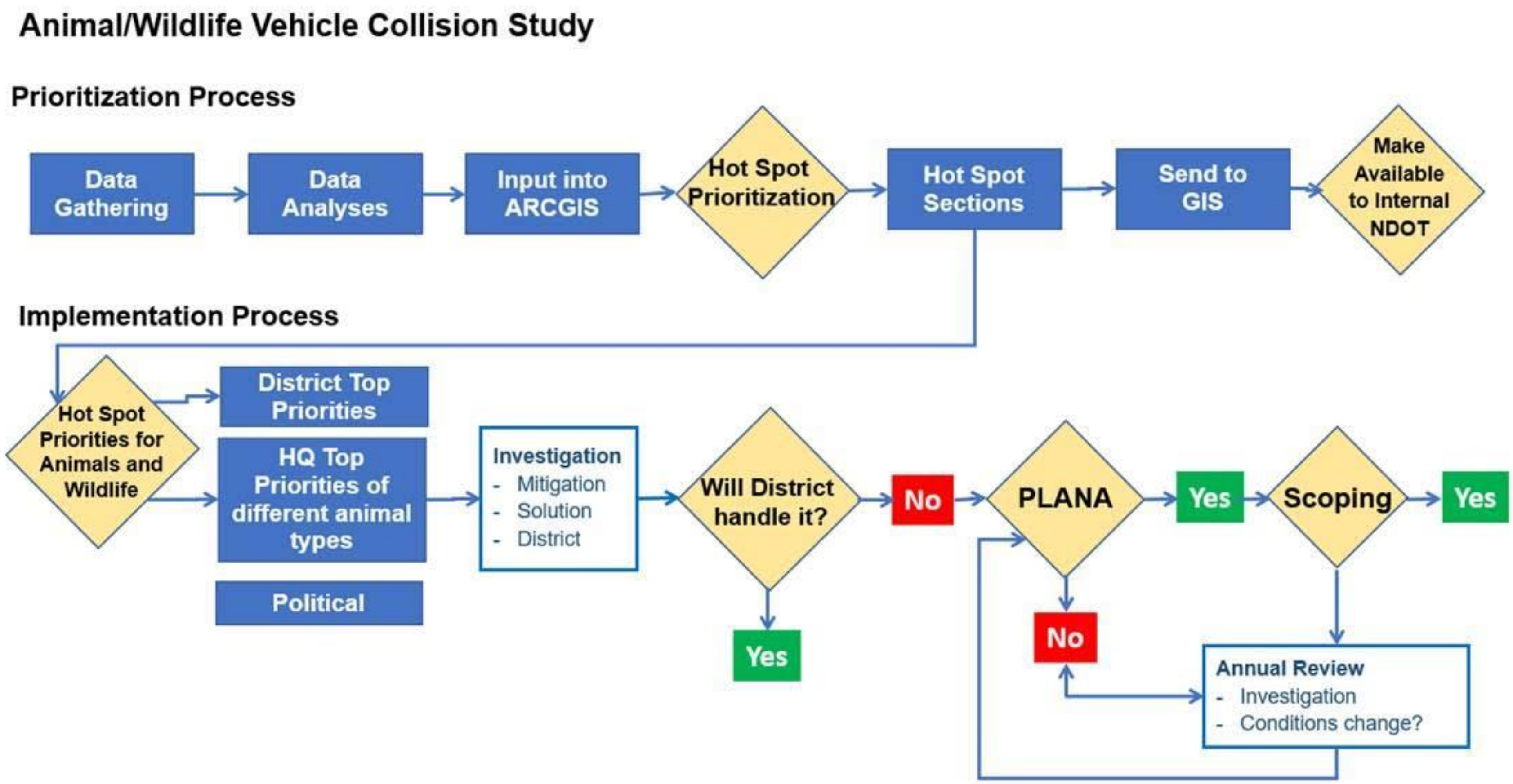


Figure 52. How the Animal-Vehicle Conflict Prioritization Maps Can Inform the NDOT Planning Process. Figure Adapted for NDOT Flow Diagrams. Courtesy of NDOT's L. Bonner.

Overview of Needs and Actions

Currently in Nevada and most U.S. states, there is no standard process of analyzing animal-related crash and carcass data across the state to identify problem animal-vehicle conflict areas. In all states, typically, when a transportation project is in the planning stages the traffic safety engineer pulls crash data for the specific road or a similar road to analyze and make recommendations for how the project can potentially address crash safety problems in the area. If there is a problem with animals, the traffic safety engineer can note this. Concurrently, there is no standardized policy that encourages DOT staff to consider these animal-vehicle collision crash data in their analysis for future and current projects, as there is no regulatory initiative to reduce animal-vehicle collisions or provide wildlife connectivity options. As a result, the very information that could help solve animal-vehicle conflict sits in its' databases and does not regularly get consulted as a standardized process to help inform potential solutions. The more proactive DOT personnel do, however, regularly consult crash, carcass and wildlife data during the project development process. They also work with their counterparts in wildlife resource agencies to address the species involved, locations for potential mitigation, and funding support. The proactive DOT's, including NDOT, are finding there is a need to standardize these actions across the state.

Step 1. Identify the Wildlife-Livestock Vehicle Conflict Priority Areas

The need is to identify areas where there are animal-vehicle conflict occurs across the state and within each NDOT district. The type of animals involved require different strategies and approaches, thus the locations, magnitude of the problem, and species involved are all important to identify the top priority areas.

The priority actions to identify where wildlife and livestock are prone to being involved in vehicle collisions are: 1. Manage and analyze crash data; 2. Collect, manage, and analyze carcass data; 3. NDOW supply updated collared animal data and habitat maps to NDOT; and 4. NDOT brings these data together to map priority locations for animal- vehicle conflict and make the maps available to NDOT personnel.

Crash Data Management and Analyses

NDOT and other agencies will continue to collect crash data. Nevada's detailed list of animals potentially involved in crashes is extremely important in addressing problems and should remain available. The PDO short form should also contain the detailed 14 species list, and is reported to have been updated as of the writing of this report.

Nevada Traffic Safety - Law enforcement crash locational data should have automatic GPS locations that are instantly geo-referenced. This would eliminate the time and errors of transposing the estimates written by officers of where they believe the location was, or where they pulled their vehicles over to input data into electronic forms.

NDOT Traffic Safety will need to establish where and how NDOT personnel, and perhaps NDOW personnel too, go to pull crash data for areas of interest. Right now there are two methods: personnel can go to the crash data requests forms website (Nevada Department of Transportation 2018b), and fill out forms for NDOT Traffic Safety, asking for specific crash and carcass data (see Nevada Department of Transportation 2018a). Or users can access the NDOT crash data through an interactive mapping website (see Nevada Department of Transportation 2018a) which is a very coarse scale hotspot map with 20-mile hexagonal bins.

The methods used in this report and documented in Appendix A will need to be standardized for animal crash data searches. These methods help extract records that did not indicate species of animal involved, but used other reporting entries, such as the crash narrative, to indicate animal species involved in the crash.

Carcass Data Collection, Management, and Analysis

Carcass data are extremely important to document the unreported extent of collisions with animals, especially wild animals that are not as common as mule deer. They also help NDOT and NDOW prescribe the correct mitigation for the species in conflict with vehicles.

Nevada DOT - Maintenance workers will need to be able to use an electronic method to upload carcass data GPS locations, species of animal, age, and gender. As of 2018 there were efforts to create such methods with iPads and iPhones.

Nevada DOT - Maintenance workers, supervisors, and overall institutional hierarchy need to be convinced that collecting data on carcasses is an important part of their job and the operations of NDOT to help find solutions to decrease crashes with animals.

Nevada DOT Maintenance personnel can be educated on the importance of carcass data collection during their education at the Maintenance Academy.

Tie paycheck reporting to carcass reporting, as Idaho Transportation Department does. This equates to having a paycheck delivered to the employee only if the time cards were turned in with carcass reports for the same period.

Create a public website for uploading carcass data, as Idaho, California, and Massachusetts do.

NDOW Update Wildlife Habitat Maps and Collar Data Maps

NDOW can be proactive in helping NDOT determine where wild animals are moving and need to move, and changes in past patterns. Working relations between the two agencies have to be tended to and regularly renewed for the exchange of information, ideas, mitigation options, and funding opportunities. The two recommendations below can assist in this relationship.

When NDOW updates habitat maps and geolocation data point maps of collared animals, these new maps and data on wildlife locations are also uploaded to NDOT GIS websites for personnel use in planning. This includes future modeling of potential ungulate migration corridors.

Create an annual NDOT - NDOW Coordination Meeting, potentially also called an Animal Safety Summit. The objective of this meeting is for NDOW staff to update NDOT on wildlife habitat and empirical data maps and important ecological information pertinent to NDOT roads. NDOW would also alert NDOT to areas where wildlife are near roads where the information is not geo-referenced, and when there are urgent or even emergency situations where there is wildlife-vehicle conflict. NDOT would update NDOW on NDOT road projects in the future, and crash and carcass data. The NDOW Wildlife Staff Specialist with GIS Coordination responsibilities could be the person to set up these meetings. See Idaho MOU, Appendix C for how these details could be spelled out.

Conduct Animal-Vehicle Conflict Hotspot Prioritization Process and Make Results Available to NDOT Staff

The hotspot prioritization process developed in this research can be used on a biennial or quinquennial (five year) basis with updated data. The generation of priority hotspots should be conducted on at least a quinquennial basis so the results can be coordinated with the development of the NDOT five-year plan. This prioritization process will create animal-vehicle collision crash hotpots, and safety and ecological hotspots that are based on many layers of georeferenced data. NDOT will need to decide how to take the different priorities and move them forward on a state-wide and district wide basis.

Lists and maps of animal-vehicle collision top priority areas should be created for the state and NDOT district levels.

NDOT will need to decide if the hotspot modeling is a responsibility of the Safety Division or the Environmental Division, and assign this responsibility to specific positions. Typically, Safety provides the data. It is up to another NDOT Division to process and interpret the data.

State headquarters uploads the new maps, statistics tables, and other data to a GIS website available to all NDOT personnel to use and notifies all NDOT personnel it is available. It can be the responsibility of NDOT Environmental (ENV) staff at headquarters to distribute and announce the new maps and data. Every NDOT district is ensured to receive these maps and lists through the ENV staff. Ensure the maps and data are delivered to project development teams, design teams, scooping teams, and to NDOT division at headquarters.

Step 2. Integrate Wildlife Considerations Into Planning

The hotspot priority areas where wildlife and livestock are in conflict with traffic along NDOT administered roads will need to be first analyzed by NDOT district staff to investigate potential mitigation solutions. If the district does not handle the steps for potential solutions, the NDOT headquarters staff will need to bring the solutions into the long range state-wide planning process.

Districts Decide to Create Stand Alone Animal Mitigation Projects or Integrate Solutions into Existing Projects

NDOT District staff will annually examine and use headquarters' data for the district's top priorities that will inform planning for both standalone wildlife and livestock mitigation projects and as an addition to plans for future projects.

NDOT District staff will annually apply a score card from this study (Table 46, below), to compare components of top wildlife and livestock-vehicle conflict areas within the district, with other areas under consideration, and decide which are the priority projects in the coming years. This score card includes analyses of information that is not typically georeferenced, such as if there is an upcoming transportation project that can incorporate mitigation actions, or if there are potential funding partners willing to assist with the cost of a project. The Table 47 scorecard was adapted from Idaho Transportation Department (ITD) analysis Dr. Cramer performed for specific sites on US 20 to determine the priority areas to place wildlife mitigation (Cramer 2016). In turn, an interactive map was created for the public to view the locations, priority rankings, and solutions generated from the study (Idaho Transportation Department 2017). This may be a possibility for NDOT districts with prioritized animal-vehicle conflict projects.

Part of the score card examination is looking at the sites of hotspots and determining the potential for retrofits that could solve the problem cost-effectively. This can be done through a process developed by Kintsch and Cramer (2011) for Washington DOT. The process has been adapted by Washington and several other states and there are standardized hard copy and electronic forms that can be filled out to help decide best courses of action.

Table 46. Scorecard for Prioritizing Segments of Road for Wildlife Mitigation Actions.

Step and Information Source	Definition	Value Description	Point Value	Actual Points
Step 1. GIS Layers	Safety GIS Layer Total Maximum Points = 50, ranked on a continuous scale by ArcGIS	Crash, carcass and AADT (potential) data, continuous values	1-50	
	Wildlife Habitat Maps & Livestock Crash Data, Maximum Points = 50, ranked on a continuous scale by ArcGIS	Ungulate & Bear habitat layers, Horse and Cattle Crash numbers	1-50	
Max = 100 Points	Total Combined GIS Map Points Maximum Score Based on Safety GIS Layer, and Wildlife Habitat Layer Ranked on a continuous scale by ArcGIS (0-100)	All above geo-referenced data	0-100	100
Step 2. NDOT-NDOW Needs Assessment NDOT Districts **Max=15 Points**	NDOT Work with NDOW to prioritize areas based on ecology not represented in Step 1 GIS analyses. 15= urgent, high need areas	Agreed one of the most urgent areas for wildlife-livestock mitigation in District, and possibly state	15	15
		NDOW or USFWS strongly suggest mitigation for species of concern	10	
		NDOW or USFWS express a sense of urgency, needs for area	5	
		No urgency or needs expressed by NDOW, or USFWS	0	
Step 3. Land Ownership **Max=5 Points**	Evaluate land ownership in the area for feasibility of creating mitigation in conjunction with protected lands. 5= protected lands.	Both sides of road are either Public land, or private w Conservation Easement	5	5
		Public or Private w/ Easement on One Side of Road & Undeveloped Private Opposite Side	4	
		Public or Private w/ Conservation Easement on One Side of road, Private & Development Opposite Side of Road	2	
		Private Undeveloped, Both Sides of Road	2	
		Private – Developed and multiple owners. Both sides	0	
Step 4. Evaluate Future	Evaluate area in relation to projects listed in Long Range, STIP, Corridor Plans, & Projects. Look for potential opportunities to	Within Upcoming Project	5	5
		Within Project in STIP, Corridor Plan	4	
		Within a Project in Long Range Plan	3	

Step and Information Source	Definition	Value Description	Point Value	Actual Points
Transportation Projects Max= 5 Points	incorporate WVC mitigation actions. 5= upcoming projects	Not in any of above plans	0	
Step 5. Look for Retrofit of Existing Structures Max=5 Points	Analyze existing infrastructure for retrofits opportunities. 5=areas with retrofit potential that would reduce costs. (PAS see Kintsch & Cramer 2011)	Existing bridge can accommodate large ungulates And can be retrofit with ease to encourage passage	5	5
		Existing bridge or culvert can accommodate some of members of the species of greatest AVC interest with minimal ease	4	
		No opportunity to retrofit for target species	0	
Step 6. Conduct Benefit-Cost Analysis for Potential Project Max=5 Points	Use crash and carcass data to estimate annual cost of no action, and use as potential benefit part of equation, to learn at what cost would the project pay for itself over lifetime of infrastructure. 5 = ratio of one and greater.	Benefits/cost ratio $\geq$ 1	5	5
		Benefit/cost ratio = 0.45 - .99	3	
		Benefit/cost ratio < 0.45	0	
Step 7. Identify Potential Funding Partners Max=10 Points	Work at district & state level to find public & private funders for mitigation. 10 = at least 25% of project can be secured outside NDOT	Partner organization contributing > 10% of project cost	10	10
		Partner organization contributing 3-10% of project cost	8	
		Contributions from 0.5-3% of project cost	6	
		No potential co-funders at this time	0	
			Total	**145**

Determine if any maintenance actions could help address these areas and conflicts. If there are potential maintenance actions, such as repairing holes in fences, fixing double cattle guards, clearing debris and vegetation from culverts, then environmental staff should deliver a report of potential maintenance driven actions to Maintenance Division Chief or head of maintenance in a district on an annual basis.

District staff investigate the potential to address animal-conflict areas with District Betterment funds, which are for projects under $ 250,000. These projects are not on the Long-Range Transportation Plan and One Nevada Plan.

NDOT District staff examine One Nevada Plan for potential projects in their district that could be in areas with animal-vehicle conflict and that could have additions that would help reduce the problem of collisions with animals while providing animal movement opportunities below or above the road.

NDOT district staff place potential wildlife and livestock related projects into One Nevada Plan.

Once NDOT personnel select top priority segments of road for potential mitigation projects within the district and for funding and project opportunities, the NDOW wildlife collar shape file should be consulted to evaluate if large mammal wildlife populations have been documented in the area (Figure 53). The data from this shape file (which will be made available to NDOT personnel with GIS electronic files from this project) can be used for evidence-based solutions for the type and locations of wildlife mitigation. This file contains 271,728 data points taken from GPS and radio collars on predominantly mule deer, but also elk, all three NDOW-recognized subspecies of mountain sheep (desert, California, and Rocky), pronghorn antelope, black bear, and puma (cougar).

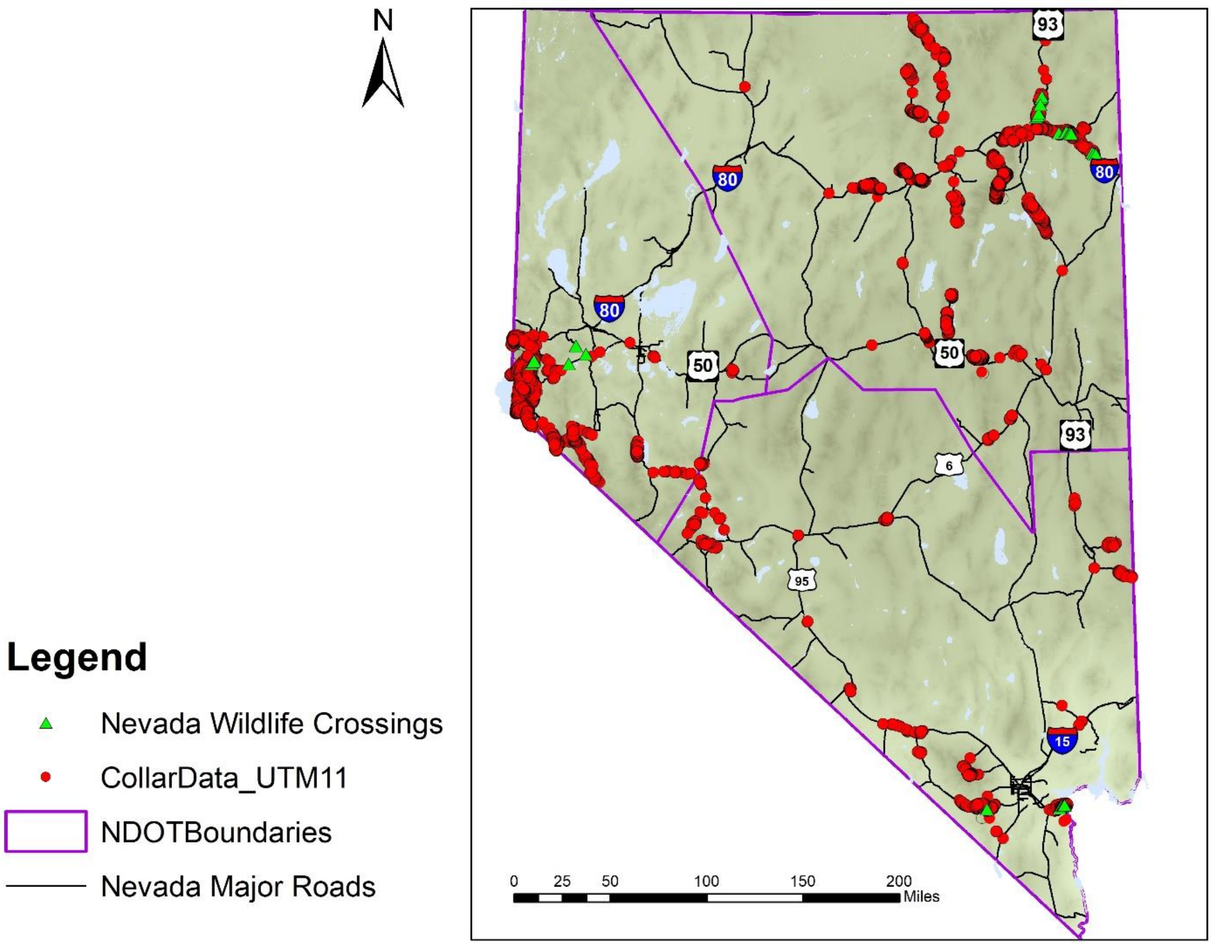


Figure 53. Collar Locational Data for Mule Deer, Elk, Bighorn Sheep, Pronghorn Antelope, Black Bear, and Puma, Buffered For Locations Within One Mile of All NDOT Roads and Highways, Developed by NDOW, 2017.

NDOT Headquarters Environmental Staff Submit PLANA Applications for Other Priority Areas

Every year NDOT environmental staff need to ensure that the top 25 statewide animal-vehicle conflict priority areas that are not being developed into projects by the districts are individually submitted to the Multi-Modal Development Chief through Planning and Needs Assessment (PLANA) project applications (Nevada Department of Transportation 2018c). Within those applications, staff ensure that the applications also include detailed descriptions of the mitigation features needed to address the wildlife-livestock vehicle conflict problem. NDOT environmental staff will meet regularly through the year with the Multi-Modal Development Chief and Chief Road Design Engineer to 'shepherd' the potential projects through the NDOT planning process. NDOT champions for wildlife mitigation must also work toward a goal of having a designation of money available for wildlife concerns in the NDOT One Nevada Funding.

NDOT district level staff can also submit these top priority areas into the PLANA process, and champion potential projects with similar actions.

NDOT should also consider placing the top three to five priority areas in the NDOT five-year plan as it is developed. As previously noted, the prioritization process should be conducted at minimum every five years in tandem with the development of the five-year plan so animal-vehicle conflict reduction projects can be inserted into the plan.

A NDOT overview of the current NDOT planning process is presented in Figure 54. It should be noted that the future planning process will change with the development of PLANA.

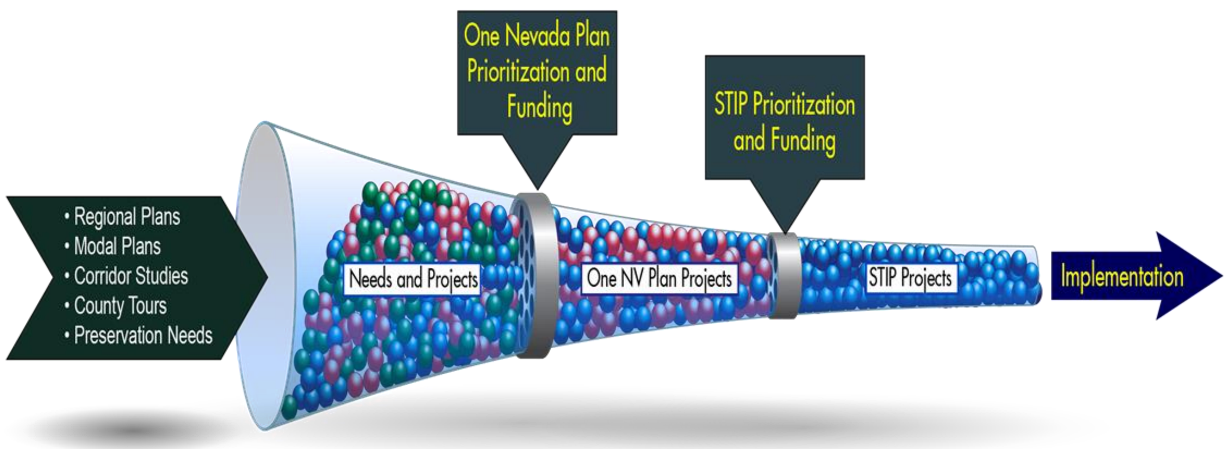


Figure 54. Nevada Department of Transportation Planning Process for Transportation Projects.

NDOW Involvement in the Planning Process

NDOW generates valuable information on where and how wildlife-vehicle conflict occur. It is critical their input be considered early in the planning process, for it will not only save wildlife, but time and money for NDOT.

NDOT district staff will be instructed to set up twice yearly meetings at minimum with NDOW counterparts, to review the STIP and upcoming projects. Details of these meetings and personnel positions responsible for maintaining high levels of communication can be dictated in a MOU, such as the ITD-IDFG MOU in Appendix C.

Step 3. Project Development and Building, Monitoring, and Adaptively Managing Mitigation Solutions

The project development process is where wildlife and livestock mitigation are created and adaptively managed. There are four sub-steps for this phase.

NDOT Environmental Staff Consult with Design, Construction, and Project Development Teams

The progress of a project depends on champions within an agency. The NDOT environmental staff, along with safety and other experts will need to guide the development of a wildlife or livestock mitigation project. NDOT environmental staff at the headquarters and district levels will need to inform Planning, Scoping, and Design Teams of the needs for such mitigation, past designs, locations of the start and end of hotspots, the problem species and the best mitigation for those species, and other important components of a project. These actions pertain to stand alone wildlife mitigation projects and as those built into existing projects.

Determine How Maintenance Staff Can Contribute

Maintenance personnel are critical to the development of wildlife and livestock mitigation and should be included from the beginning of project development. They will also need to be informed how their role is critical to maintaining the infrastructure over time. As the monitoring of a mitigation project progresses, there are inevitably adaptive management actions necessary to increase the effectiveness of the culverts, bridges, fencing, double cattle guards, escape ramps, and other components. Maintenance personnel will be critical to creating these adaptive management strategies.

NDOT-NDOW Collaboration

During the project development process and the monitoring and adaptive management phases of mitigation, NDOW should be involved and kept abreast of results. NDOW wildlife biologists have monitored NDOT wildlife mitigation projects in the past and can provide these services and important advice in future projects. Their input as to what is happening on the ground with wildlife, and wild animal reactions to mitigation, roads, and traffic are all critical to creating effective mitigation structures, fencing and other components of the mitigation projects.

Scientists Monitor Mitigation and Make Recommendations

The scientists that monitor wildlife mitigation infrastructure can greatly assist NDOT and NDOW in wildlife crossing structure, fence, escape ramp, and wildlife deterrent designs. The monitoring project can create performance measures as to how the infrastructure is expected to perform for wildlife and in reducing wildlife-vehicle collisions. These performance measures can be decided by a panel and used to declare if the mitigation was successful. The monitoring can also reveal potential adaptive management actions necessary to improve infrastructure performance. The monitoring project can also generate photos, videos, and data to help support the creation of additional wildlife crossing structures. Ms. Simpson's master's thesis work is an example of how this has been conducted in Nevada and continues to inform future projects (Simpson 2012, Simpson et al. 2016).

The above actions are presented in a systematic manner to help NDOT and NDOW understand how each is part of a greater overall process. Below, some of those recommendations are presented more formally, along with additional actions.

Additional Actions NDOT and NDOW Can Take to Proactively Improve Mitigating Roads for Animals

There is a need for several agency procedures and approaches to be adapted to better help NDOT reduce collisions with animals. These include recommendations below.

Standardize Biennial to Quinquennial Mapping of Animal-Vehicle Conflict Areas

The results of this research will need to be replicated in future years with incoming data. NDOT will need to contract out to consultant the processes developed in this research on a biennial to quinquennial (five year) basis. This includes mapping animal-related crashes, carcass data, wildlife habitat maps, and other components described in chapters and appendices in the report.

Create a Memorandum of Understanding between NDOT and NDOW

This MOU would designate specific roles each agency has in the pick up of carcasses and the reporting of data on all species collected; bi-annual meetings at the district level to discuss upcoming projects for potential accommodations for wildlife and livestock and chances for discussions; sharing of wildlife location data from studies and mapping procedures; and other aspects of how the agency may already work together but have not become standardized and formally agreed upon. See Appendix C for Idaho MOU example.

Create an Electronic Carcass Data Collection System for Use by NDOT and NDOW

The technology exists and is used in several western states for maintenance and contract workers to use Global Positioning Systems (GPS) technology to upload the location of a carcass and then a pull-down menu to select the species, gender, and any other information deemed important. This electronic upload is key to better collecting, mapping and understanding the data that will help determine the location and most appropriate wildlife mitigation.

NDOT Work with NDOW and Potentially Create a Second Memoranda of Agreement

This MOA would facilitate NDOW uploading of wildlife habitat data, and a sub-set of wildlife collar locations to NDOT database-workbench for NDOT personnel to work with in following wildlife-vehicle conflict protocol to mitigate roads for wildlife. This would occur when habitat maps are updated, which is approximately every decade, or sooner in the future. The position within NDOT to coordinate these data uploads could be the Biological Supervisor, or Environmental Services Manager. NDOW should also update NDOT on emergent urgent situations when wildlife populations are in potential conflict with vehicles. This could be situations when elk are migrating across roads and there is a need to warn motorists with variable message boards, or a population of bighorn sheep reside near a highway and are in danger of dying out due to vehicle collisions. It is important that this occur at a local level, and that personnel for both agencies at the headquarters levels be informed as well.

Standardize Future Nevada Traffic Safety Conferences

Ensure that there is always included at least one talk and potentially a session on wildlife and livestock mitigation planning, construction, and research results in every annual Nevada Traffic Safety Conference.

In Maintenance Academy Include a Unit on Carcass Data Collection and Reporting

New NDOT Maintenance employees attend the Maintenance Academy training. A standard unit on the importance of carcass data collection and reporting could greatly increase compliance in the coming years and provide critical data as to where animal-vehicle conflict occurs, regardless of crash data.

Enlist Nevada Counties to Collect Carcass Data

County officials, law enforcement, and NDOW personnel have a more detailed knowledge of animal-vehicle conflict hotspots in the state than the NDOT state-wide data provide. If counties could be persuaded to collect and share animal carcass data along NDOT administered roads, NDOT and partner agencies could better address problem areas. This could be done with the future electronic uploading method developed for carcass collection.

Summary

In summary, the above actions standardize how data collection, mapping, planning and interagency coordination can all become routine and transparent. These improved data collections and sharing actions among NDOT staff and with NDOW staff will all greatly improved Nevada's program of making roads safer for motorists while providing wildlife connectivity beneath and above roads.

CHAPTER 9 NEVADA'S WILDLIFE MITIGATION PLAN

Introduction

Nevada's Wildlife Mitigation Plan summarizes the major findings and recommendations of this research. It is meant to be a short document that can be distributed to interested parties.

Each year there are over 500 reported animal-vehicle collision crashes on Nevada Department of Transportation (NDOT) administered roads. These crashes cost Nevadans over 19 million dollars, kill up to 5,032 or more wild animals, cause dozens of human injuries and at least one human fatality annually. Nevada can reduce these crashes and help to protect both motorists and animals by standardizing actions across NDOT and NDOW. These actions are summarized below.

Priority Hotspots for Crashes with Animals and Areas of Potential Wildlife-Vehicle Conflict

This research determined priority vehicle crash hotspots across the state for all animals, and then only wildlife, horses, and cattle. Half-mile segments of all NDOT administered roads were analyzed with a one-mile search distance for neighboring segment's animal-vehicle collision crashes using the Getis-Ord Statistical Analysis tool in ArcGIS. The hotspots were ranked based on number of crashes per mile over the ten years of data (2007-2016). See Figure 55 and Table 47 for the top animal-vehicle collision crash hotspots, where they occur, the number of crashes in those segments, and the species of wild and domestic animals involved in those crashes.

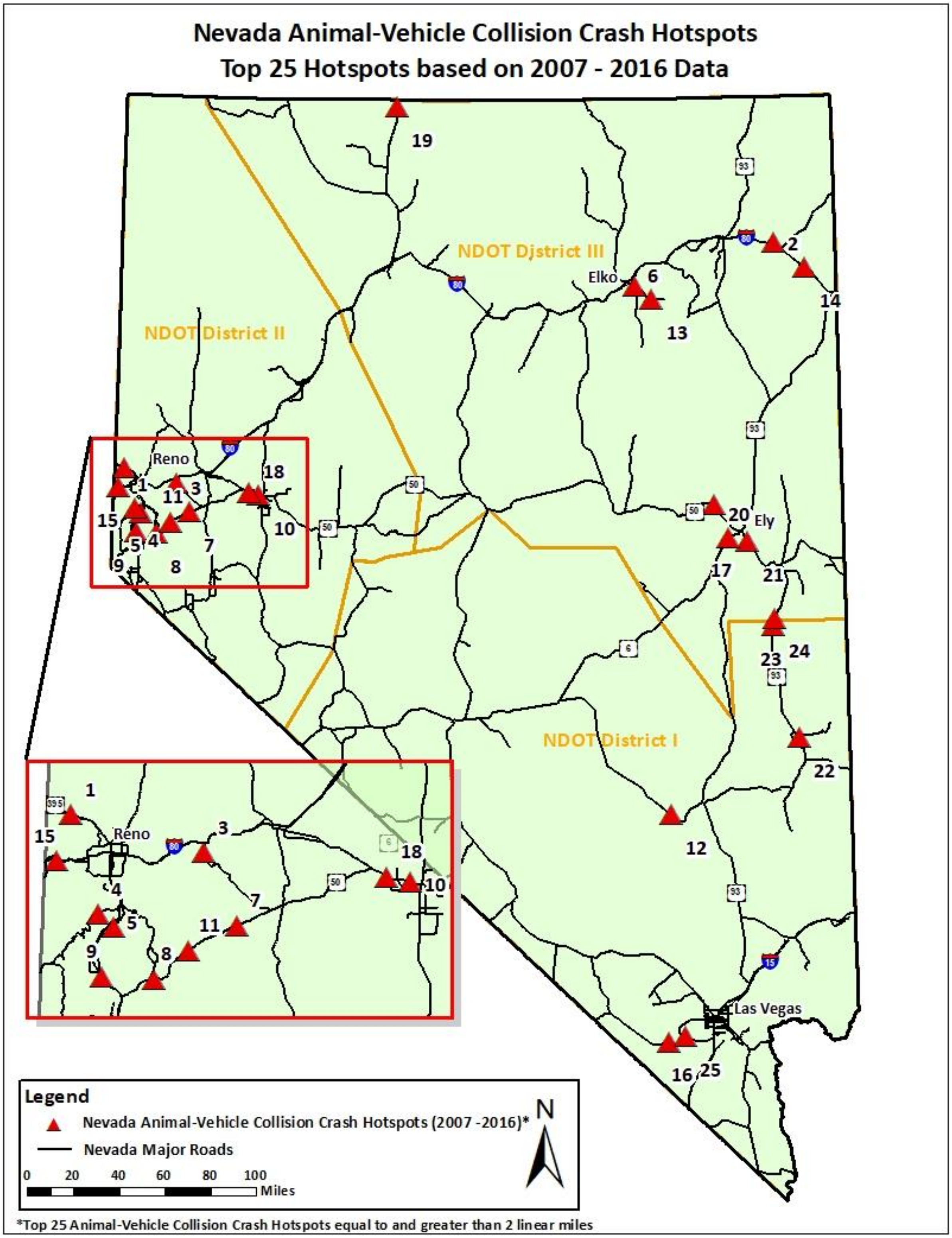


Figure 55. Map of Nevada's Top 25 Priority Reported Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles Long, Based on 2007-2016 Data, Derived From Getis-Ord Analysis 95 Percent and Greater Confidence Intervals.

Table 47. Description of Animals Involved in Nevada's Top 25 Animal-Vehicle Collision Crash Hotspots Equal to or Greater Than Two Miles in Length, from 2007-2016 Nevada Department of Transportation Crash Data.

Yellow Shading = NDOT District I, Green = District II, and Pale Blue = District III Hot Spots.

Yellow Shading = NDOT District I	*Green = NDOT District II*	*Pale Blue = NDOT District III*
Rank	**Name**	**Notes on Species, Mitigation, Landscape Factors**
1	US 395 Granite Peak	Mule deer were involved in 55 out of 59 crashes. Dog/coyote were the remaining crashes. Water north of the road may be part of the need for mule deer to move.
2	I-80 Pequop Summit	Two Overpasses, fencing to existing 2 bridges & 2 culverts placed in 2017. 98 percent of crashes were with mule deer.
3	USA Highway Clark Mountain	Horses were involved in 30 of the 34 recorded crashes. Highest priority horse crash hotspot in state.
4	SR 431 Mount Rose Foothills	Mule deer were involved in 42 of 46 crashes. There were 2 horses, and one bear involved in AVC. MM 19 has most crashes, but there is no MM 18 in GIS file, so may be administrative.
5	US 395A Pleasant Valley	Both 395, and I-580. Diversity of species. Number one was mule deer, but there were also 7 horse crashes, 2 cattle, 2 bear, and 1 dog/coyote crash. 395, MM 13 is number 16 horse hotspot, MM 11 is the 25 hotspot for horses.
6	SR 227 Elko Hills	Out of 34 crashes, deer are listed involved in 24. Two dog/coyote, and 2 cattle crashes. Others unknown or not listed.
7	US 50 Horse Fence End	All 17 reported crashes were with horses. Number 3 horse hotspot.
8	US 50 Dayton	Majority of crashes were horses, Deer crashes = 12, 3 dog/coyote. Number 2 horse crash hotspot. Hotspot includes first mile north on SR 341.
9	I-580 & US 395A South Washoe Lake	Diverse animal species: Deer=37 crashes, Bear=3, Coyote/dog=3, mountain lion=1. Major wildlife movement linkage from mountains to foothills and water. Number 5 wildlife hotspot.
10	US 50 West Fallon	Deer are 15 out of 19 crash involved animals. Two cattle, 2 dog/coyote crashes. The majority of crashes occurred near the canal on the west side of town, where Coleman and Casey Roads bisect US 50.
11	US 50 Carson Plains	Horses were involved in 12 out of 15 crashes. One deer and 3 dog/coyote crashes were the other animal types.
12	SR 375 Tikaboo Valley	Cattle were involved in 24 out of 26 crashes. Top cow hotspot in state. One pronghorn. Open Range.
13	SR 227 Spring Creek	South of Elko, Deer crashes were 23 out of 26 crashes. Dog/coyote were 3 crashes.
14	I-80 Silver Zone	Wildlife Overpass, Fencing to Two Bridges Placed in 2013. Mule deer were involved in 23 of 26 crashes, 1 dog/coyote, 2 elk. A major mule deer migration linkage.
15	I-80 Stateline to Reno	Out of 90 crashes, mule deer were involved in 72 crashes, 4 bear, 4 dog/coyote, 1 cattle, 1 bird, 2 unknown animals. The location is a biodiverse area with mountains, foot hills, and the Truckee River running along the highway.

Yellow Shading = NDOT District I		*Green = NDOT District II*	*Pale Blue = NDOT District III*
Rank	**Name**	**Notes on Species, Mitigation, Landscape Factors**	
16	SR 160 Mountain Springs	Of the 26 crashes were the species was identified, 20 = mule deer, 3 = elk, 2 dog/coyote, and 1 burro. NDOT has a wildlife crossing structure schedule to be built at this site in 2019.	
17	US 6 Western Eagan Range Foothills	This mountainous area has three ungulate species killed: 1 bighorn sheep, 1 cattle, 5 elk, and 22 mule deer.	
18	US 50 Fallon-Ragtown	Of the 32 crashes in the area, 20 were with mule deer. There were 7 dog/coyote and 5 cattle crashes.	
19	US 95 Oregon Border	Cattle were involved in 16 out of 17 crashes. One horse. Number 2 cattle hotspot in state	
20	US 50 Eagan Range Robinson Summit	The is predominantly a mule deer hotspot: all but one crash were mule deer. The other crash was with an elk.	
21	US 6 Steptoe Valley Wildlife Management Area	This hotspot has three ungulate species killed in crashes: 2 pronghorn, 8 elk, and 11 mule deer. This area is tied for the second highest elk hotspot for crashes.	
22	US 93 Pioche	Multiple roads in and out of Pioche, entire area a hotspot for mule deer and horses. The area has 3 of the top horse hotspots.	
23	US 93 Wambolt Springs	This is the number 1 elk hotspot in the state: out of 26 crashes, 17 were with elk. Deer = 8 crashes, cattle = one.	
24	US 93 Travis Reservoir	This area is tied for the second highest elk crash site: 8 elk crashes, deer=3, 1 each of pronghorn antelope, cattle, and dog/coyote.	
25	SR 159 Blue Diamond	This is the burro hotspot in the state. Out of 66 crashes in the area, 56 were with burros, deer = 7, 1 dog/coyote, 2 unknown animals. Note this is both SR 159 and SR 160 intersection.	

Crash hotspots with only wildlife species were also prioritized. The top 25 priority hotspots for wildlife-vehicle collision reported crashes were calculated and mapped over NDOW habitat data for mule deer and elk, Figure 56.

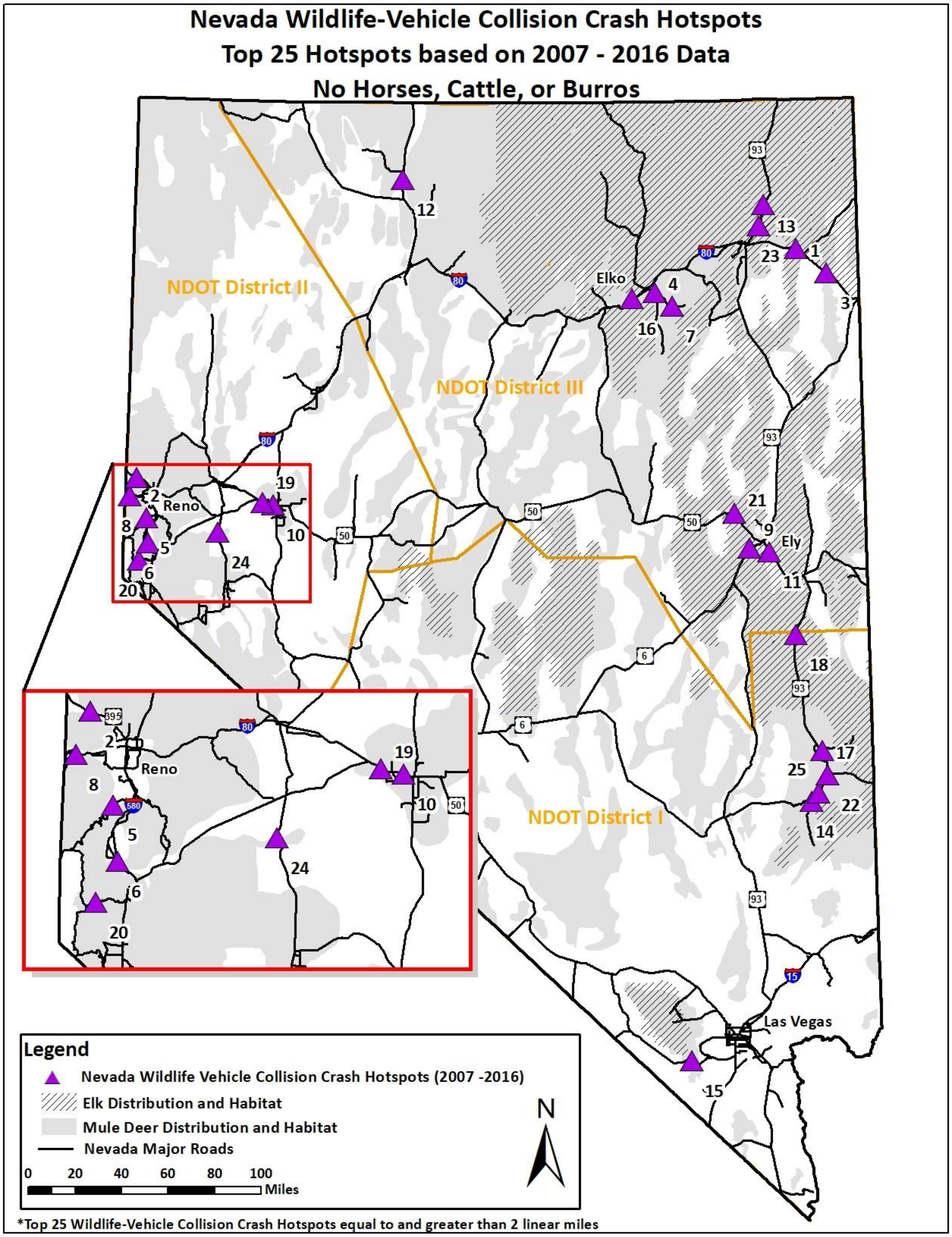


Figure 56. Top 25 Wildlife-Vehicle Collision Crash Hotspots in Nevada 2007-2016, based on Getis-Ord 95 Percent and Higher Confidence Interval. No Horses, Cattle, or Burros. Hotspots Laid Over Mule Deer and Elk Habitat Maps from Nevada Department of Wildlife.

While these crash priority locations may be a partial predictor of future crashes, identifying the potential for wildlife-vehicle conflict based on both safety data and ecological data is a more holistic proactive approach than modeling past reported crashes. The researchers created a second map modeling approach by generating a safety map and an ecological map and then combining them with scores for each half-mile segment of NDOT roads. The safety map layer scored each half mile segment of road based on average annual daily traffic (AADT), percentage of crashes that were animal-related, animal-vehicle collision crash, and carcass data. The ecological map included score card values based on wildlife habitat and corridor maps plus horse and cattle hotspot maps. Each of the two layers was worth 50 points. The map layers were combined for each half mile segment of NDOT administered roads. Each half mile segment of road was ranked with respect to the total tally of points from these two maps. The resulting top 25 hotspots were then considered animal-vehicle conflict hotspots, based on safety and ecological data, Figure 57. Table 48 presents where each of these priority areas are in Nevada.

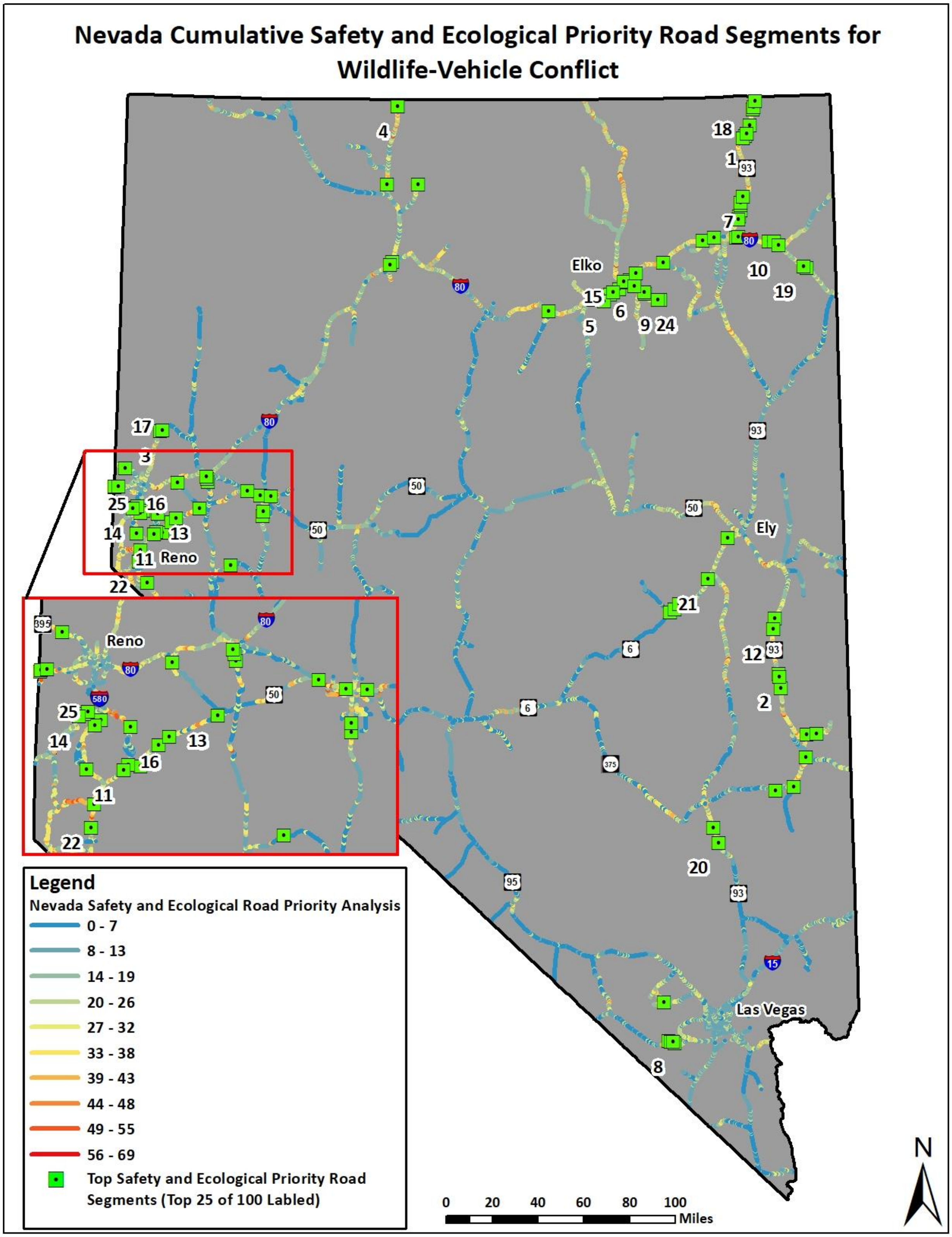


Figure 57. Animal-Vehicle Conflict Top 25 Hotspot Priority Locations Numbered, and Top 100 Locations Represented, Based on Ecological and Safety Data, 2007-2016.

Table 48. Top 25 Hotspots of Animal-Vehicle Conflict Based on Safety and Ecological Data.

Rank	Road	Potential Name = Road, Location, and Mile Marker	Mile Markers*	Length Miles	Safety Value	Ecological Value	Total Points	If in a Getis-Ord Animal-Crash Hotspot, Rank?	District
1	US 93	US 93 Table Top Mountain	US 93 EL 123-126	3.0	32	37	69	No	III
2	US 93	US 93 Fairview Range	US 93 LN 147-148.4	1.4	32	37	67	No	I
3	SR 445	SR 445 Mullen Creek	WA 24.5 - 25	0.5	30	35	65	No	II
4	US 95	US 95 Quinn River Valley	US 95 HU 69 – 71.5	2.5	30	34	64	No	III
5	I-80	I-80 Moleen-Humboldt River	I-80 EL 8 - 12	4.0	48	15	63	No	III
6	SR 227	SR 227 Spring Creek Area	SR 227 EL 2 -6	4.0	38	25	63	No	III
7	US 93	US 93 North of Wells	US 93 EL 94 - 95	1.0	43	20	63	No	III
8	SR 160	SR 160 Mountain Springs	CL 19.7 – 23.3	3.6	43	18	61	16	I
9	SR 227	SR 227 Pleasant Valley	SR 227 EL 17.5 - 18	0.5	36	25	61	0	III
10	I-80	I-80 Pequop Summit	I-80 IR 94 - 100	6.0	36	25	61	2	III
11	US 50	US 50 - SR 341 Intersection	US 50 LY 0 – 5.1 SR 341 LY 0 – 1.1	6.2	49	12	61	8	II
12	US 93	US 93 LI - WP County Line	US 93 LN 169 - 171	2.0	30	30	60	0	I
13	US 50	US 50 Horse Fence End	US 50 LY 24 - 25	1	40	20	60	7	II
14	SR 431	Mt. Rose Highway	WA 18 – 20.3	2.3	40	20	60	4	II
15	I-80	I-80 West Elko	EL 15 - 17	2.0	40	20	60	0	III
16	US 50	US 50 Dayton	US 50 LY 13 – 14.5	1.5	37	22	59	8	III
17	SR 445	SR 445 Mullen Pass	WA 25.5 - 26	0.5	37	22	59	0	II
18	US 93	US 93 Table Top Mountain S	I-80 EL 121.5 - 123	1.5	32	27	59	0	III
19	I-80	I-80 Silver Zone	I-80 IR 113.5 - 117	3.5	39	20	59	14	III
20	US 93	US 93 Pahranagat Valley	LN 31.7 – 32.2	0.5	28	30	58	0	I
21	US 6	US 6 Currant	US 6 WP 9.7 -10.2	0.5	28	30	58	0	I
22	US 395	US 395 Carson River	DO 28.6 - 29.1	0.5	41	17	58	0	II
23	I-80	I-80 Carlin	I-80 EL 4.5 - 7	2.5	38	20	58	0	III
24	SR 227	SR 227 Lamoille	SR 227 EL 16.5 - 17	0.5	33	25	58	0	III
25	SR 431	Mt. Rose - Whites Creek	WA 20.8 – 21.3	5.0	40	17	57	6	II

** Mile Markers Name Abbreviation for County of Occurrence: CL=Clark, DO=Douglas, EL=Elko, HU=Humboldt, IR = Iron, LN=Lincoln, LY=Lyon, WA=Washoe, and WP= White Pine.*

The next steps in the Nevada Wildlife Mitigation Plan is to take the information from the hotspot modeling and top Wildlife-Vehicle Conflict areas and inform transportation planning to create wildlife and livestock mitigation.

Implementation Plan Recommendations

The implementation plan for next steps after this research can be summarized in three main steps: Identify wildlife and livestock-vehicle conflict priority areas, integrate wildlife considerations into planning, and in project development, build, monitor and adaptively manage wildlife mitigation, Figure 58. This plan is intended to create a standardized methodology to be carried out at NDOT headquarters and within the districts. It assigns responsibilities to various divisions within NDOT, NDOT districts, and to NDOW.

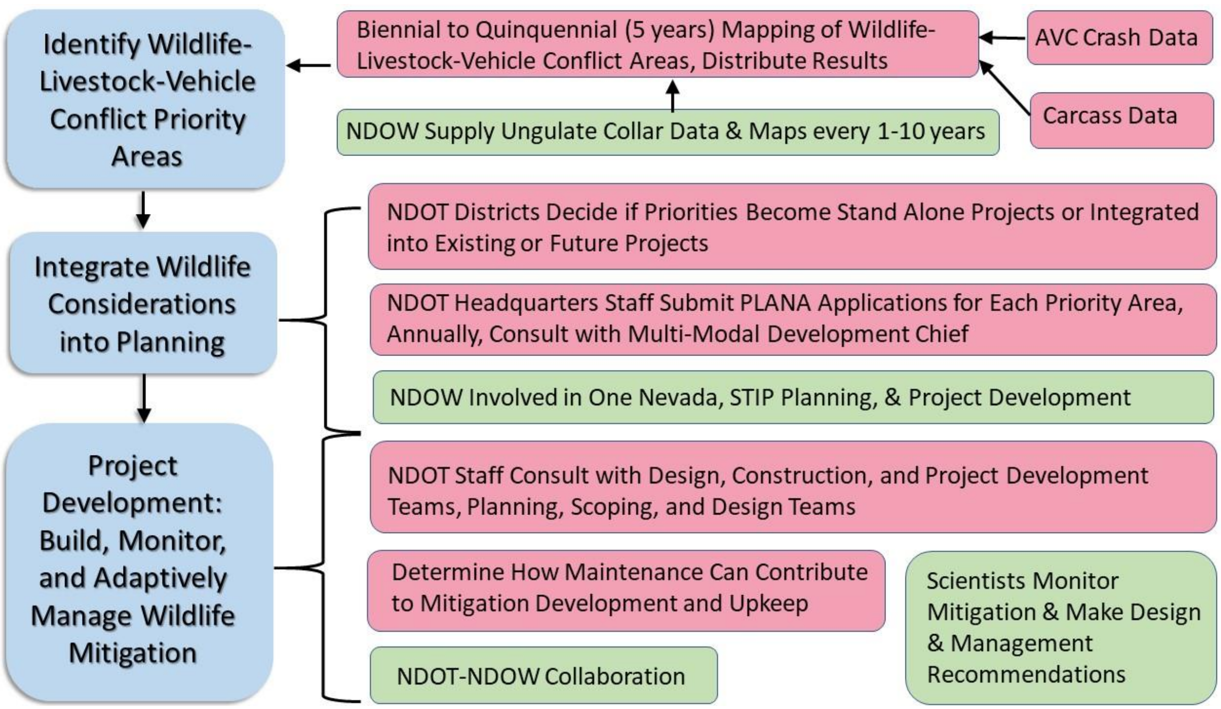


Figure 58. The Three Major Steps for Mitigating Roads for AVC and the Information and Actions That Support Each Step.
*Pink Boxes Represent NDOT Actions, and Green Boxes Represent NDOW Actions***.** *Figure adapted from Cramer et al. 2016***.**

Step 1. Identify the Wildlife-Livestock Vehicle Conflict Priority Areas

The need is to identify areas where there are animal-vehicle conflicts across the state and within each NDOT district. The type of animals involved require different strategies and approaches, thus the locations, magnitude of the problem, and species involved are all important to identify the top priority areas.

1. Crash Data Management and Analyses – Nevada shall work to establish automatic GPS upload of crash location, and a standardized place and process for pulling crash and carcass data with reference to any animals.
2. Carcass Data Collection, Management, and Analysis – train new maintenance employees at the Maintenance Academy about the importance of carcass data collection, provide an electronic upload of carcass data from the field, convince maintenance personnel, perhaps with promise of punitive actions if not upheld, that carcass data collection and upload are critical components of their positions, and potentially create a public website where the public and county personnel can upload carcass data.
3. NDOW Update Wildlife Habitat Maps and Collar Data Maps – NDOW to upload new maps and empirical GPS collar data to NDOT website for inclusion in project development. Also, NDOT and NDOW should create an annual Animal Safety Summit to work together on identifying and solving animal-vehicle conflict priority areas in Nevada.
4. Conduct Animal- Vehicle Conflict Hotspot Prioritization Process and Make Results Available to NDOT Staff – NDOT will need to assign responsibility of creating future high priority hotspots maps to either the Environmental or Traffic Safety Division. The mapping should be done from every two to every five years, especially just before the development of the NDOT five-year plan. The hotspot analyses should be carried out in the same manner this research details. NDOT Environmental should upload all the new data and maps to the NDOT shared GIS portal for personnel to use and notify staff when the products are ready.

Step 2. Integrate Wildlife Considerations Into Planning

The hotspot priority areas where wildlife and livestock are in conflict with traffic along NDOT administered roads will need to be first analyzed by NDOT district staff to investigate potential mitigation solutions. If the district does not handle the steps for potential solutions, the headquarters NDOT staff will need to bring the solutions into the long range state-wide planning process, see Figure 59.

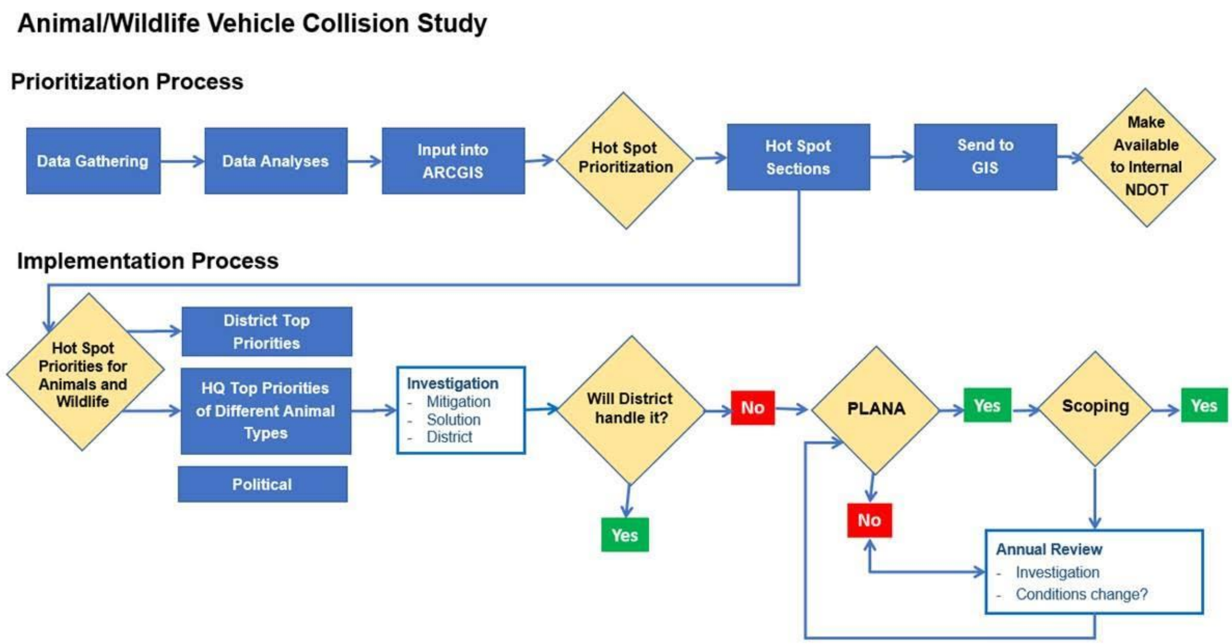


Figure 59. Nevada Department of Transportation Flow Diagram for How Implementation of This Study Could be Incorporated into NDOT Planning Process. Map Courtesy of L. Bonner, NDOT.

5. Districts Decide to Create Stand Alone Animal Mitigation Projects or Integrate Solutions into Existing Projects – NDOT district staff, headed by the environmental staff, annually examines the top animal-vehicle conflict hotspots and decides what areas are to be submitted as standalone projects, and what hotspot solutions could be combined with future or existing projects. These actions can be facilitated with the score card supplied in this report, that can rank priority areas within a district or along a road. The environmental staff also will need to visit each site with a Passage Assessment System (PAS, Kintsch and Cramer 2011) score card to look for potential retrofit solutions. District staff can also look for potential retrofits and solutions that maintenance personnel could address in every day actions. District environmental staff shall also consult NDOW map of collared animal locations within one mile of NDOT administered roads to look for evidence of populations of animals, especially mule deer, moving across the highway of concern, and use this as documentation of the potential conflict.
6. NDOT Headquarters Environmental Staff Submit PLANA Applications for Other Priority Areas – For projects not escorted through the planning process by district staff, headquarters environmental and traffic safety staff place remaining hotspots into the PLANA process (Nevada Department of Transportation 2018c) as applicants for potential projects. Headquarters' staff shall meet regularly with the Multi-Modal Development

Chief and Chief Road Design Engineer to 'shepherd' the potential projects through the NDOT planning process.

7. NDOW Involvement in the Planning Process shall include at minimum twice yearly meetings with NDOT counterparts at both the headquarters and district levels. These interactions shall be mandated and organized according to a Memorandum of Understanding between the two agencies and fashioned after a similar Idaho agreement (provided in Appendix C).

The above actions can be guided in part by the lists of top priority crash and Safety-Ecological map of Potential Wildlife-Vehicle Conflict segments of NDOT roads. Below, Tables 49, 50, and 51 present the top priority areas for each NDOT district. NDOT personnel at the headquarters' and districts' levels can use these tables to help prioritize actions according to the recommendations above. Future mapping and prioritization processes can update these tables.

Table 49. NDOT District I Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse-Crash Hotspots, Cattle-Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
SR 375 Tikaboo Valley	US 93 LN 10 - 11	US 93 Caliente Newman Canyon	US 93 Newman Canyon	Extra Terrestrial Highway South Tikaboo Valley	US 93 Fairview Range
SR 160 Mountain Springs	SR 375 LN20 - 21	SR 160 Mountain Springs	US 93 North of Pioche	Extra Terrestrial Highway North Tikaboo Valley	SR 160 Mountain Springs
US 93 Pioche	US 93 LN 91.5 - 93.3	US 93 Pioche	US 93 East Pioche	Extra Terrestrial Highway Mid Tikaboo Valley	US 93 Lincoln-White Pine County Line
US 93 Wambolt Springs	US 93 LN 36 - 36.5	US 93 Wambolt Springs-Travis Reservoir	US 93 Caliente Meadow Valley	ARNY 44 Ralston Valley	US 93 Pahranagat Valley
SR 159 Blue Diamond		US 93 Panaca	SR 360 Candelaria Hills	SR 361 North Gabbs	US 6 Currant
		US 93 Caliente Meadow Valley	US 6 SR 360 Intersection	SR 170 Mesquite	
			US 6 Humboldt-Toiyabe National Forest	ARNY 44 Monitor Hills	
			US 6 Mineral Esmerelda County Line	US 95 South Mina	
			US 93 Grassy Springs Pioche	Extra Terrestrial Highway Railroad Valley	
			US 93 North Pioche		
			SR 264 Fish Lake Valley		

Table 50. NDOT District II Crash Hotspots 2007-2016 for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, Horse Collision Crash Spots, Cattle-Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections > 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
US 395 Granite Peak	US 95A LY 34.4 - 36	US 395 Granite Peak	USA Parkway I-80 Junction and South	US 50 Lahontan Reservoir	SR 445 Mullen Creek
USA Highway Clark Mountain	US 50 CH 23.2 - 24.3	SR 431 Mount Rose Foothills	US 50 Dayton	US 50A & US 95A South Fernley	US 50 - SR 341 Intersection
SR 431 Mount Rose Foothills	I-580 WA 5.2 - 6.7	I-580 & US 395A South Washoe Lake	US 50 Horse Fence End	SR 270 & 115 South Side of Fallon	US 50 Horse Fence End
US 395A Pleasant Valley	US 50 LY 13 - 14.5	I-80 Stateline to Reno	US 50 Carson Plains	US 50 East Side of Fallon	Mt. Rose Highway
US 50 Horse Fence End	US 50 LY 24 - 25	US 50 West Fallon	US 50A North of Silver Springs	US 95 Walker River	US 50 Dayton
US 50 Dayton	SR 445 WA 24.5 - 26	US 50 Fallon-Ragtown	US 50A South Fernley	SR 400 Dunn Glenn Flat	SR 445 Mullen Pass
I-580/ US 395 South Washoe Lake	SR 118 CH 1.5 - 2	US 50 I-580 West Carson City	US 50 Carson Plains	SR 445 South Pyramid Lake	US 395 Carson River
US 50 West Fallon	SR 659 WA 2.4 - 3	US 95A Stillwater National Wildlife Refuge	SR 341 Virginia City	US 50 & SR 116 Fallon-Harmon Reservoir	Mt. Rose - Whites Creek
US 50 Carson Plains		US 395A Steamboat Hot Springs	SR 341 Steamboat	SR 117 West Edge of Fallon	
I-80 Stateline to Reno		US 95 Walker Lake	Mount Rose Highway	SR 447 East Pyramid Lake	
US 50 Fallon-Ragtown		US 50 & USA Highway Intersection		SR 121 Dixie Valley	

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Horse	Cattle	Safety and Ecological
		US 395A Pleasant Valley		US 50A & US 95A Wabuska	

Table 51. NDOT District III Hotspots for All Animal-Vehicle Collision Crashes Sections Two Miles and Longer, Less Than Two Miles, Wildlife-Vehicle Collision Crash Hotspots, and Safety and Ecological Hotspots.

All Animals Sections ≥ 2 Miles	All Animals Sections < 2 Miles	Wildlife	Cattle	Safety and Ecological
I-80 Pequop Summit	I-80 EL 63.5 – 64	I-80 Pequop Summit	US 95 Oregon Border	US 93 Table Top Mountain
SR 227 Elko Hills	I-80 HU 12 - 13.5	I-80 Silver Zone	Grass Valley Road South Winnemucca	US 95 Quinn River Valley
SR 227 Spring Creek	I-80 EU 3 - 3.2	SR 227 Elko Hills	SR 789 Getchel Road-Kelly Creek	I-80 Moleen-Humboldt River
I-80 Silver Zone	US 93 EL 125 - 125.5	SR 227 Spring Creek	I-80 East Winnemucca	SR 227 Spring Creek Area
US 6 Western Eagan Range Foothills	I-80 EU 17.7 - 18.3	US 6 Western Eagan Range Foothills		US 93 North of Wells
US 95 Oregon Border	SR 157 CL 5 - 5.5	US 6 Steptoe Valley Wildlife Management Area		SR 227 Pleasant Valley
US 50 Eagan Range Robinson Summit	US 95 HU 39.5 - 41	US 95 Quinn River Valley		I-80 Pequop Summit
US 6 Steptoe Valley Wildlife Management Area	US 6 WP 56.5 - 58	US 93 HD Summit		I-80 West Elko
US 93 Travis Reservoir	I-80 EL 30 - 31	I-80 Humboldt River		US 93 Table Top Mountain S
	US 93 EL 67.5 - EL 68	US 50 Eagan Range Robinson Summit		I-80 Silver Zone
	US 6 WP 8 - 8.5	US 93 Ten Mile Summit		I-80 Carlin
	US 6 W 8.5 - 10			SR 227 Lamoille

Step 3. Project Development and Building, Monitoring, and Adaptively Managing Mitigation Solutions

The project development process is where wildlife and livestock mitigation are created and adaptively managed. There are four sub-steps for this phase.

8. NDOT Environmental Staff Consult with Design, Construction, and Project Development Teams. Project development and progress rely on champions, and NDOT environmental staff will need to guide the development of a project over the years it takes to fruition. NDOT environmental staff at the headquarters and district levels will need to inform Planning, Scoping, and Design Teams of the needs for such mitigation, past designs, locations of the start and end of hotspots, the problem species and the best mitigation for those species, and other important components of a project.
9. Determine How Maintenance Staff Can Contribute, this includes their involvement from the beginning of planning for a project to the adaptive management phase of a project when small changes will need to be made to adjust infrastructure so it performs optimally in keeping animals off the road and moving beneath or above in wildlife crossing structures.
10. NDOT-NDOW Collaboration is necessary during the project development process and the monitoring and adaptive management phases of mitigation. NDOW should be involved and kept abreast of results. NDOW wildlife biologists have monitored NDOT wildlife mitigation projects in the past and can provide these services and important advice in future projects
11. Scientists Monitor Mitigation and Make Recommendations. Most wildlife and livestock mitigation that involves the building of culverts, bridges, or overpasses should be monitored. Double cattle guards and new designs of escape ramps and fencing should also be monitored to help develop measures with optimum effectiveness. Performance measures can be created with a monitoring project and can be used by the research panel to declare if the mitigation was a success and effective and what needs to be adapted. Continued adaptive management is necessary for most projects and monitoring helps evaluate how effective it is.

The above actions are presented in a systematic manner to help NDOT and NDOW understand how each is part of a greater overall process. Below, additional recommendations are presented.

Additional Actions NDOT and NDOW Can Take to Proactively Improve Mitigation of Roads for Animals

12. Create a Memorandum of Understanding between NDOT and NDOW for carcass pick up, data sharing, twice yearly meetings and potentially a wildlife summit, and planning.
13. Standardize Future Nevada Traffic Safety Conferences to include sessions on wildlife and livestock mitigation planning, construction, and research results.
14. In Maintenance Academy Include a Unit on Carcass Data Collection and Reporting.
15. Enlist Nevada Counties to Collect Carcass Data Once Electronic Method is Established.
16. Officers and deputies need an automated GPS location upload of their crash locations.
17. Research all new wildlife mitigation, both pre-construction and post construction.
18. Create performance measures at the start of the research and determine if the infrastructure met the goals.
19. NDOT Environmental personnel will be trained in prioritization process overall, how to hire consultants to repeat, and how to upload the information for all NDOT personnel.
20. NDOT Traffic Safety personnel who handle crash data will be trained on how to extract animal related crash data from the overall crash database.
21. NDOT Environmental personnel will be trained in how to use PLANA to both submit animal-vehicle conflict hotspots, and provide input all along the project development process.
22. Headquarters and district personnel trained on how to use the road segment score card presented in Table 52 below, to compare among different road segments for priority actions.
23. Environmental staff and engineers that have designed wildlife crossing structures, work together to upload diagrams, plans, photos and cost estimates to a central location. These personnel then work together to inform the remaining NDOT personnel these are available for reference for future projects.
24. Also, if the escape ramps, double cattle guards, wildlife guards, wildlife exclusion fence, horse exclusion fence, wildlife and horse box culvert, wildlife corrugated steel culverts, bridges, and overpasses are not standardized in NDOT operating manuals, this must be done, based on research on the effectiveness of these infrastructure.
25. NDOW should ensure that all wildlife movement studies supported by NDOW that have any components where animals were detected near roads or need to cross roads should report the effect of roads and upload all GPS locational data that may be within one mile of roads for the greater wildlife and roads database.
26. NDOW biologists and GIS specialists will need to upload new habitat and corridor maps to NDOT's GIS portage.
27. Special recommendations for horses and cattle:

Wild horses pose a serious danger to motorists. Mitigation measures for these animals are an important part of a wildlife mitigation plan, even though these animals are considered livestock. With the priority horse-vehicle conflict locations identified in this report, NDOT can work with the BLM and other public natural resource agencies to:

- Place variable message boards near the top wild horse collision hot spots, warning motorists of the potential for crashes, seasonally, diurnally, meaning make the signs come on a different times of day and year. A display of the ongoing count of the number of horses killed in the current year will help keep locals' attention.
- Install horse restrictive fencing in these areas, along with round bar cattle guards at road and driveways, because horses can find ways to walk over flat bar double cattle guards.
- NDOT should plan for additional horse underpass structures near the top horse-vehicle conflict hotspots.
- Work with BLM and other agencies to reduce the wild and feral horse populations, especially near roads.

Cattle are present on roads in open range areas. In an era where the U.S. is poised to allow self driving cars navigate the roads, the fact that Nevada lacks fencing to keep these animals off the road is very antiquated. The maps of cattle highest priority crash areas can help NDOT work with partner agencies to erect and repair right-of-way fencing and place cattle guards at egress and ingress points. Nevada may want strengthen any laws for punitive actions against cattle owners complacent in cattle accessing highways.

Table 52. Scorecard for Prioritizing Segments of Road for Wildlife Mitigation Actions.

Step and Information Source	Definition	Value Description	Point Value	Actual Points
Step 1. GIS Layers	Safety GIS Layer Total Maximum Points = 50, ranked on a continuous scale by ArcGIS	Crash, carcass and AADT (potential) data, continuous values	1-50	
	Wildlife Habitat Maps & Livestock Crash Data, Maximum Points = 50, ranked on a continuous scale by ArcGIS	Ungulate & Bear habitat layers, Horse and Cattle Crash numbers	1-50	
Max = 100 Points	Total Combined GIS Map Points Maximum Score Based on Safety GIS Layer, and Wildlife Habitat Layer Ranked on a continuous scale by ArcGIS (0-100)	All above geo-referenced data	0-100	100
Step 2. NDOT-NDOW Needs Assessment NDOT Districts **Max=15 Points**	NDOT Work with NDOW to prioritize areas based on ecology not represented in Step 1 GIS analyses. 15= urgent, high need areas	Agreed one of the most urgent areas for wildlife-livestock mitigation in District, and possibly state	15	15
		NDOW or USFWS strongly suggest mitigation for species of concern	10	
		NDOW or USFWS express a sense of urgency, needs for area	5	
		No urgency or needs expressed by NDOW, or USFWS	0	
Step 3. Land Ownership **Max=5 Points**	Evaluate land ownership in the area for feasibility of creating mitigation in conjunction with protected lands. 5= protected lands.	Both sides of road are either Public land, or private w Conservation Easement	5	5
		Public or Private w/ Easement on One Side of Road & Undeveloped Private Opposite Side	4	
		Public or Private w/ Conservation Easement on One Side of road, Private & Development Opposite Side of Road	2	
		Private Undeveloped, Both Sides of Road	2	
		Private – Developed and multiple owners. Both sides	0	
Step 4. Evaluate Future	Evaluate area in relation to projects listed in Long Range, STIP, Corridor Plans, & Projects. Look for potential opportunities to	Within Upcoming Project	5	5
		Within Project in STIP, Corridor Plan	4	
		Within a Project in Long Range Plan	3	

Step and Information Source	Definition	Value Description	Point Value	Actual Points
Transportation Projects Max= 5 Points	incorporate WVC mitigation actions. 5= upcoming projects	Not in any of above plans	0	
Step 5. Look for Retrofit of Existing Structures Max=5 Points	Analyze existing infrastructure for retrofits opportunities. 5=areas with retrofit potential that would reduce costs. (PAS see Kintsch & Cramer 2011)	Existing bridge can accommodate large ungulates And can be retrofit with ease to encourage passage	5	5
		Existing bridge or culvert can accommodate some of members of the species of greatest AVC interest with minimal ease	4	
		No opportunity to retrofit for target species	0	
Step 6. Conduct Benefit-Cost Analysis for Potential Project Max=5 Points	Use crash and carcass data to estimate annual cost of no action, and use as potential benefit part of equation, to learn at what cost would the project pay for itself over lifetime of infrastructure. 5 = ratio of one and greater.	Benefits/cost ratio ≥ 1	5	5
		Benefit/cost ratio = 0.45 - .99	3	
		Benefit/cost ratio < 0.45	0	
Step 7. Identify Potential Funding Partners Max=10 Points	Work at district & state level to find public & private funders for mitigation. 10 = at least 25% of project can be secured outside NDOT	Partner organization contributing > 10% of project cost	10	10
		Partner organization contributing 3-10% of project cost	8	
		Contributions from 0.5-3% of project cost	6	
		No potential co-funders at this time	0	
			Total	**145**

Wildlife Mitigation Plan Summary

This report delivers data, maps, and recommendations for Nevada to use in planning, construction, maintenance and research approaches to animal mitigation along roads. There are roles for most personnel in NDOT, and several important positions within NDOW. In the coming years the actions prescribed in this plan will help Nevada reduce animal-vehicle collisions, and wildlife-vehicle conflict, thereby making the roads safer for all who travel Nevada roads, while still allowing animals to move to critical habitat and resources on different sides of roads. This report is an important step in that direction.

CHAPTER 10 SUMMARY AND CONCLUSIONS

The research and synthesis presented in this report help prescribe the steps Nevada will need to take going forward in efforts to reduce animal-vehicle conflict. Through the analyses of crash and wildlife data, and predictive potential mapping of wildlife-vehicle conflict, the research demonstrated the top priority areas where Nevada agencies and the public need to begin addressing mitigation options for the reduction of these potential conflicts while allowing wild and feral animals to move beneath and above roads to access critical resources.

Through the literature review and investigations into what other western U.S. states have accomplished, the report presents options on how Nevada can update its collection of carcass data, its transportation planning processes, and its working relations between NDOT and NDOW.

Nevada has demonstrated an enormous capacity to rapidly install and monitor wildlife crossing structures, especially overpasses for wildlife. The forward thinking personnel in NDOT will undoubtedly take the results of this study and continue this trajectory of becoming leaders in the field of establishing wildlife and livestock mitigation and making roads safer for the public. As they progress in this field, not only Nevada but the entire U.S. will learn and benefit from these actions.

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APPENDIX A. NEVADA DEPARTMENT OF TRANSPORTATION AND SISTER AGENCIES’ PROCESSES FOR COLLECTING WILDLIFE-VEHICLE CRASH AND CARCASS DATA, AND HOW THE DATA WERE MAPPED IN THIS RESEARCH

Introduction and Overview of NDOT Process for WVC Crash and Carcass Data Collection and Use

Crash and Carcass Data Reporting

Crash data are collected by safety officers and deputies in the field when called to a vehicle crash scene. The threshold value of damage to a vehicle for a report to be filed is $1,500. Officers use the Traffic Accident Report (Form 5) (Figure 60) or Property Damage Only (PDO) form which are electronically uploaded to NDOT’s citation and crash reporting software vendor. Some law enforcement agencies use paper forms on the scene of the crash, however, these are then encoded and entered into crash reporting software. These forms are uploaded to the Nevada software vendor site managed by Tyler Technologies.

The Traffic Accident Reporting Form (Form 5, see below) has several entries important for mapping collisions with wildlife. Form 5 and the PDO form both have entry boxes for officers to enter the location of the crash by listing the primary street with a mile marker (mile post, MP) or a cross street. The officer then determines the offset, distance and direction, in feet from this intersection to specify the crash location.

Form 5 also has a section titled, ‘Roadway/Environmental Factors.’ In this section there is an option (number 14) to check ‘Animal in Roadway.’ Information about animals can also be entered in the section, ‘Vehicle’s Sequence of Events’ on the last page of Form 5.

A section on the first page of Form 5 is titled, ‘First Harmful Event.’ Form 5 code list for the collision with a person, motor vehicle, or movable object; there are nine different codes to fill out for animals, Figure 61.

The PDO form was updated in 2016 to have these options to check boxes to record animal involvement, and officers can only enter animal information in the narrative. This narrative section can be queried for all records at a later time to learn if the officer recorded if an animal was involved.

Event Number:

Code Revision: 01/01/2016

STATE OF NEVADA
TRAFFIC CRASH REPORT
SCENE INFORMATION SHEET
Revised 01/2016

Crash Number: **Scene Information**

☐ 1) Property ☐ 2) Injury ☐ 3) Fatal

☐ 1) Urban ☐ 2) Rural | ☐ 1) Emergency Use ☐ 2) Office Report | ☐ 1) Preliminary Report ☐ 2) Initial Report ☐ 3) Resubmission ☐ 4) Supplement Report | ☐ 1) Hit and Run ☐ 2) Private Property

Agency Name:

Crash Date	Time	Day	Beat / Sector	☐ 1) County	☐ 2) City
/ /					

Mile Marker	# Vehicles	# Non Motorists	# Occupants	# Fatalities	# Injured	# Restrained

Occurred On: *(Highway # or Street Name)*
☐ 1) Parking Lot ☐ 2) Active School Zone

☐ 1) At Intersection With:
☐ 2) Or ☐ 3) Feet ☐ 4) Miles ☐ 5) Approximate Of (Cross Street)

Surface
☐ 1) Asphalt ☐ 2) Concrete ☐ 3) Gravel ☐ 4) Dirt ☐ 5) Other

Intersection
☐ 1) Four Way ☐ 2) > Four Way ☐ 3) T ☐ 4) Y ☐ 5) Roundabout ☐ 6) Other ☐ 7) L

Paddle Markers
☐ 1) None ☐ 2) Left Side ☐ 3) Right Side ☐ 4) Both Sides ☐ 5) Unknown

Access Control
☐ 1) None ☐ 2) Full ☐ 3) Partial

Roadway Character
☐ 1) Curve & Grade ☐ 2) Curve & Hillcrest ☐ 3) Curve & Level ☐ 4) Straight & Grade ☐ 5) Straight & Hillcrest ☐ 6) Straight & Level ☐ 7) Unknown ☐ 8) Other

Roadway Conditions
☐ 1) Dry ☐ 2) Icy ☐ 3) Wet ☐ 4) Snow ☐ 5) Sand / Mud/ Dirt / Gravel ☐ 6) Other ☐ 7) Slush ☐ 8) Standing Water ☐ 9) Moving Water ☐ 10) Unknown ☐ 11) Oil

Total Thru Lanes
Main Road ☐ 1) One ☐ 2) Two ☐ 3) Three ☐ 4) Four ☐ 5) Five ☐ 6) > 5
Total All Lanes:

Average Roadway Widths
Travel Lane Ft
Storage / Turn Lane Ft
Median Ft
Paved Shoulder: Inside / Outside

Roadway Grade
☐ 1) Not Determined ☐ 2) Relatively Level Roadway ☐ 3) Up Slope (+) ☐ 4) Down Slope (-)
Relative To
Grade %

Pavement Markings
☐ 1) Centerline, Broken Yellow ☐ 2) Centerline, Solid Yellow ☐ 3) Centerline, Double Yellow ☐ 4) Lane Line, Broken White ☐ 5) Land Line, Solid White ☐ 6) No Passing, Either Direction ☐ 7) Turn Arrow Symbols ☐ 8) Center Turn Lane Line ☐ 9) Edge Line, Left Yellow ☐ 10) Edge Line, Right White ☐ 11) Other ☐ 12) None ☐ 13) Unknown

Roadway Description
☐ 1) Two-Way, Not Divided ☐ 2) Two-Way, Divided, Unpro, Median ☐ 3) Two-Way, Divided, Median Barrier ☐ 4) One-Way, Not Divided ☐ 5) Unknown ☐ 6) Off Road

Weather Conditions
☐ 1) Clear ☐ 2) Cloudy ☐ 3) Snow ☐ 4) Rain ☐ 5) Blowing Sand, Dirt, Soil ☐ 6) Other ☐ 7) Fog, Smog, Smoke, Ash ☐ 8) Severe Crosswinds ☐ 9) Sleet / Hail ☐ 10) Unknown ☐ 11) Blowing Snow

Light Conditions
☐ 1) Dark ☐ 2) Dawn ☐ 3) Daylight ☐ 4) Unknown ☐ 5) Other ☐ 6) Dark—No Roadway Lighting ☐ 7) Dark—Spot Roadway Lighting ☐ 8) Dark—Continuous Roadway Lighting ☐ 9) Dark—Unknown Roadway Lighting

Vehicle Collision Type
☐ 1) Head On ☐ 2) Rear End ☐ 3) Backing ☐ 4) Angle ☐ 5) Rear to Rear ☐ 6) Sideswipe - Meeting ☐ 7) Sideswipe - Overtaking ☐ 8) Non Collision ☐ 9) Unknown ☐ 10) Rear to Side

Location of First Event
☐ 1) Travel Lane ☐ 2) Turn Lane ☐ 3) Gore ☐ 4) Median ☐ 5) Inside Shoulder ☐ 6) Outside Shoulder ☐ 7) Intersection ☐ 8) Private Property ☐ 9) Roadside ☐ 10) Other ☐ 11) Ramp ☐ 12) Unknown ☐ 13) Separator ☐ 14) Parking Lane/Zone

Roadway / Environment Factors
☐ 1) None ☐ 2) Weather ☐ 3) Debris ☐ 4) Glare ☐ 5) Other Roadway ☐ 6) Other Environmental ☐ 7) Shoulders ☐ 8) Road Obstruction ☐ 9) Worn Traffic Surface ☐ 10) Wet, Icy, Snow, Slush ☐ 11) Ruts, Holes, Bumps ☐ 14) Animal in Roadway ☐ 15) Unknown ☐ 16) Visual Obstruction ☐ 17) Backup Prior Crash ☐ 18) Backup Non Recurring Incident ☐ 19) Backup Regular Congestion ☐ 20) Work Zone ☐ 21) Non Highway Work ☐ 22) Railway Grade Crossing # ☐ 23) Shared User Path/Trail

Type of Work Zone
☐ 1) Lane Closure ☐ 2) Lane Shift/Crossover ☐ 3) Work on Shoulder or Median ☐ 4) Intermittent/Moving Work ☐ 5) Other

Work Area Zone
☐ 1) Advanced Warning Area ☐ 2) Transition Area ☐ 3) Activity Area ☐ 4) Termination Area

Workers Present
☐ 1) Yes ☐ 2) No

Law Enforcement Present
☐ 1) No ☐ 2) Officer Present ☐ 3) LE Vehicle Only Present

Property Damage To Other Than Vehicle
Describe Property Damage:
Owner's Name: ☐ 1) Owner Notified
Owner's Address: (*Street Address City, State Zip*)

First Harmful Event | Code # | Description:

Investigation Complete	Photos Taken	Scene Diagram	Statements	Date Notified	Time Notified	Arrival Date	Arrival Time
☐ 1) Yes ☐ 2) No	☐ 1) Yes ☐ 2) No	☐ 1) Yes ☐ 2) No	☐ 1) Yes ☐ 2) No #	/ /		/ /	

Investigator(s)	ID Number	Date	Reviewed By	Date Reviewed	Page of
		/ /		/ /	

Figure 60. Traffic Accident Report Form 5. Areas Pertinent to Mapping Wildlife-Vehicle Collisions Highlighted in Yellow.

STATE OF NEVADA FORM 5 CODE LIST (REVISED 01/2016)

Scene Information sheet codes

Day Codes

1- Sunday	2- Monday	3- Tuesday	4- Wednesday	5- Thursday	6- Friday	7- Saturday

Use the following codes to complete the "First Harmful Event" located on the Scene Information sheet, and the "Sequence of Events" and "Most Harmful Event" located on the Vehicle Information and Non Motorist Information sheets.

Non-Collision:

101 – Overturn / Rollover
102 – Fire / Explosion
103 – Immersion
104 - Jackknife
105 - Cargo / Equipment Loss or Shift
106 - Equipment Failure (Blown tire, Brake failure, etc.)
107 – Separation of Units
108 – Ran Off Roadway Right
109 – Ran off Roadway Left
111 – Other Non-Collision
112 – Unknown Non Collision
113 – Thrown or Falling Object
114 – Cross Median
115 – Cross Centerline
116 –Downhill Runaway
117 – Fell/Jumped from MV
118 – Re-entering Roadway

Collision with Person, Vehicle or Movable Object:

201 – Pedestrian
202 – Pedal Cyclist
203 – Railway Vehicle
204 – Dog/Coyote
205- Burro
206 - Cattle
207 – Deer
208 – Horse
209 – Bear
210 – Antelope
211 – Big Horn Sheep
212 - Elk
213 – Other Animal
214 – Motor Vehicle in Transport (Moving Vehicle)
215 – Parked Motor Vehicle
216 – Work Zone Maintenance Equipment
217 – Slow / Stopped Vehicle
218 – Other Movable Object
219 – Unknown Movable Object
220 – Struck by falling, shifting cargo or anything set in motion by motor vehicle
221 – Other Non Motorist

Collision with Fixed Object:

301 – Impact Attenuator/Crash Cushion
302 – Bridge Overhead Structure
303 – Bridge Pier or Abutment
304 - Bridge Parapet End
305 – Bridge Rail
306 – Guardrail Face
307 - Guardrail End
308 – Median Barrier
309 – Rdwy Traffic Sign Post
310 – Overhead Sign Support
311 – Light/Luminary Support
312 – Utility Pole
313 – Other Post, Pole or Support
314 - Culvert
315 – Ditch
316 – Embankment
317 – Tree / Shrub
318 – Mailbox
319 – Fence / Wall
320 – Other Fixed Object (Building, Tunnel, etc.)
321 – Work Zone
322 – Unknown Fixed Object
323 – Cable Barrier
324 – Curb
325 – Concrete Traffic Barrier
326 – Other Traffic Barrier
327 – Traffic Signal Support

Use the following codes to complete the Vehicle Information and/or Non-Motorist information sheets

Seating Position:

1 – 1 st Row – Left Side (Motorcycle Driver)
2 – 1 st Row – Middle
3 – 1 st Row – Right Side
4 – 2 nd Row – Left Side (Motorcycle Passenger)
5 – 2 nd Row – Middle
6 – 2 nd Row – Right Side
7 – 3 rd Row – Left Side (Motorcycle Passenger)
8 – 3 rd Row – Middle
9 – 3 rd Row – Right
10 - Sleeper Section of Cab (Truck)
11 – Passenger in Other Enclosed Passenger or Cargo Area (non-trailing unit such as a bus, etc.)
12 – Passenger in Unenclosed Passenger or Cargo Area (non-trailing units such as a pickup etc.)
13 – Trailing Units
14 – Riding on Vehicle Exterior (non-trailing unit)
15 – Unknown
16 – 4 th Row – Left Side
17 – 4 th Row – Middle
18 - 4 th Row – Right Side

Occupant Restraints:

0 – Not Applicable
1 – Not Installed
2 – Not Used
3 – Used Shoulder Belt Only
4 – Improper use of Shoulder Belt
5 – Used Lap Belt Only
6 – Improper Use of Lap Belt
7 – Used Shoulder and Lap Belt
8 – Improper Use of Shoulder and Lap Belt
10 - Improper Use of Child Safety Seat
12 – Improper Use of Helmet
13 – Restraint Use Unknown
14 – Unknown
15 – Child Restraint System – Forward Facing
16 – Child Restraint System – Rear Facing
17 – Booster Seat
18 – Child Restraint Type Unknown
19 – DOT-Compliant Motorcycle Helmet
20 – Other Helmet
21 - No Helmet

Person Type:

1 – Driver
2 – Passenger
3 – Witness
4 – Pedestrian
5 – Pedal Cyclist
6 – Skater
7 – Wheelchair
8 – Other Cyclist
10 – Other Non Motorist
88- Unknown

Driver License Status:

0 – Valid
1 – Normal with Restrictions
2 – Violation beyond Restriction
3 – Suspended
4 – Revoked
5 – Endorsements Violation
6 – No Valid Drivers License
7 – Expired License
8 – No License Required
9 – Cancelled or Denied
10 – Disqualified (CDL)
88 - Unknown

Figure 61. Form 5 Code List for Collisions with Animals Highlighted.

Carcass data are collected by NDOT maintenance personnel using the form below, Figure 62. The form has an entry to place route and mile marker, along with other road features, a list of potential species to check, gender and age class of the animal boxes to check, and a comments section. Maintenance personnel either: 1. Call in the information to their local dispatch who create electronic versions; or 2. Enter the information on paper data sheets in the field and then transfer the data to the electronic versions of the forms. All electronic reporting forms are then sent to NDOT Traffic Safety at CrashInfoRequests@dpt.nv.gov.

NEVADA DOT SAFE AND CONNECTED

NEVADA DEPARTMENT OF WILDLIFE

Dead Animal Report Form

Date: ____ **NDOT DISTRICT** I **Crew:** ____

Route: **SR** ____ (No.) **Travel Side:** **(Select One)** **County:** ____ **MP:** ____

Or **Location:** ____

Animal Type: (Enter number of animals found next to type)

____ **Deer**	____ **Mountain Lion**	____ **Cow**
____ **Elk**	____ **Bobcat**	____ **Horse**
____ **Antelope**	____ **Bear**	____ **Burro**
____ **Bighorn Sheep**	____ **Tortoise**	____ **Sheep or Goat**
____ **Hawk, Owl, Eagle**	____ **Other:** ____	

Gender: (check if known) **M** ☐ **F** ☐ **Age Class** (if known) **Adult** ☐ **Juvenile** ☐

Comment: ____

E-Mail or Fax to:	NDOT Traffic Safety Engineering CrashInfoRequests@dot.state.nv.us	Phone: 775-888-7334 Fax: 775-888-7403	Entered: ____

Figure 62. Nevada Dead Animal Report Form for Carcasses Along Roads.

Crash and Carcass Data Transfer to Geo-Referenced Spatial Data

Crash and carcass data are reported by road and estimated distance to nearest mile marker, but are not ready to be mapped until those estimates are translated into geo-referenced data. This is done by the NDOT transportation analysts in the Division of Traffic Safety and Engineering with the aid of software developed in-house. The tasks of mapping and merging these databases require accurate knowledge of how the data are entered, and the geo-referencing systems used by the two data entry methods. For example, NDOT maintenance workers indicate carcasses location by typically giving the road number, closest mile marker and making an approximation of how many feet the carcass was located from the mile marker, which is input as an approximation of the mile post. These locations are named according to state or county roads, such as either State Cummulative or County Cummulative mile marker. Crash data reported by officers approximated in a similar fashion and are stored in the Tyler Technologies database.

NDOT transportation analysts query the crash and carcass data and create a point location geometry for each entry using NDOT's road network to find the location based on the Primary Street, Secondary Street or Mile Marker, and the offset. They then determine the offset, distance and direction, in feet from this intersection to give the crash location. Coordinates are then calculated based on the point data's location on the map. Once geo-referenced, the crash data are then sent to Nevada's Enterprise IT Services (EITS) database called NCATS. NDOT retrieves a copy of the NCATS data from EITS to store in an Oracle database which is used by the NDOT Division of Traffic Safety and Engineering for data analysis.

Prior to October 1, 2006, officers were able to code animal involvement in the crash Form 5, but the crash location information up to this point was not translated into geo-referenced GIS crash data. The crash locations prior to this date remain in tabular format, and are not translated for use in spatial analyses. Thus, all spatial analyses of locations of crashes begin with the October 1, 2006 date.

Methods Used in This Research to Map Crash and Carcass Data

Nevada Crash and Carcass Data Compilation

The NDOT crash and carcass data were delivered to the researchers by NDOT. NDOT personnel Jason Gonzales (formerly of NDOT) and others in his group, including Nick Bacon, geo-referenced, cleaned up, and compiled crash and carcass data for statistical analyses, and created the initial maps for this project. All reported crashes that indicated wildlife or livestock were involved were compiled by Mr. Gonzalez for the dates from January 1, 2006 through

December 31, 2015. Mr. Gonzales obtained and cleaned up the ten years of animal-related crash data, with severity code, latitude and longitude, and narratives. As mentioned above, the reporting of involvement of an animal is optional if the crash is PDO. There may be wild animal species' names in the narratives, but no standard place for the information in the PDO short forms was used by law enforcement. As a result, identifying animal-related crashes involved several steps to find entries with any mention of animals. First the crash database from January 1, 2006 to December 31, 2015 was queried for all crashes where the entry for animal involved was checked in the Form 5 box 'Roadway/Environmental Factors' or if a code was given for an animal involvement in the Form 5 box, 'First Harmful Event.' The SQL language query is presented below in Table 53. Prior to October 1, 2006, the locations of crashes were not translated into geo-referenced data. So as a second step, Mr. Gonzalez filtered all reported WVC crashes from January 1 through September 30, 2006, and translated the tabular reporting of the crash locations into geo-referenced data for this study.

Table 53. SQL Query Created by Jason Gonzales of NDOT, to Locate All Mention of Wild and Domestic Animals Involved in Reported Crashes.

```
SELECT
NCATSDW.CRASH_INFO_ACC.ACCIDENT_NUM, NCATSDW.CRASH_INFO_ACC.CRASH_DATE,
NCATSDW.CRASH_INFO_ACC.CRASH_SEVERITY_DESC,
NCATSDW.CRASH_INFO_ACC.FACTORS_ENV,
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT,
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS,
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS
FROM
NCATSDW.CRASH_INFO_ACC
INNER JOIN NCATSDW.ACC_NARRATIVE
ON NCATSDW.CRASH_INFO_ACC.ACCIDENT_NUM =
NCATSDW.ACC_NARRATIVE.ACCIDENT_NUM
WHERE
NCATSDW.CRASH_INFO_ACC.CRASH_DATE >= TO_Date('2006/01/01 12:00:00AM',
'YYYY/MM/DD HH:MI:SSAM') AND NCATSDW.CRASH_INFO_ACC.CRASH_DATE <
TO_Date('2016/01/01 12:00:00AM', 'YYYY/MM/DD HH:MI:SSAM')
AND
(
NCATSDW.CRASH_INFO_ACC.FACTORS_ENV LIKE '%ANIMAL IN ROADWAY%' OR

NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%DOG/COYOTE%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%BURRO%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%CATTLE%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%DEER%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%HORSE%' OR
```

```
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%BEAR%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%ANTELOPE%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%BIG HORN SHEEP%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%ELK%' OR
NCATSDW.CRASH_INFO_ACC.FIRST_HARM_EVENT LIKE'%OTHER ANIMAL%'OR

NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%DOG/COYOTE%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%BURRO%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%CATTLE%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%DEER%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%HORSE%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%BEAR%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%ANTELOPE%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%BIG HORN SHEEP%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%ELK%' OR
NCATSDW.CRASH_INFO_ACC.V1_SEQ_EVENTS LIKE'%OTHER ANIMAL%'OR

NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%DOG/COYOTE%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%BURRO%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%CATTLE%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%DEER%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%HORSE%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%BEAR%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%ANTELOPE%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%BIG HORN SHEEP%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%ELK%' OR
NCATSDW.CRASH_INFO_ACC.V2_SEQ_EVENTS LIKE'%OTHER ANIMAL%' OR

NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% COYOTE %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% COYOTES %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% BURRO %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% BURROS %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% DONKEY %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% MULE %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% CATTLE %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% COW %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% COWS %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% DEER %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% HORSE %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% HORSES %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'%BEAR %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% ANTELOPE %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% BIG HORN SHEEP %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% SHEEP %' OR
```

```
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% ELK %' OR
NCATSDW.ACC_NARRATIVE.NARRATIVE LIKE'% ANIMAL %')
AND
(
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%IRON HORSE%' AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%BEARING%' AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%DEER RUN%' AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%COYOTE CORNER%' AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%DEER SPRINGS%'AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%ANTELOPE WAY%'AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%BEAR CREEK%'AND
NCATSDW.ACC_NARRATIVE.NARRATIVE NOT LIKE'%CATTLE GUARD%')
```

Third, Mr. Gonzales queried and filtered all ten-year crash database narratives for words that mentioned an animal was involved in the description or comment sections of the database. The fields “FIRST_HARM_EVENT”, “V1_SEQ_EVENTS”, and “V2_SEQ_EVENTS” are uniform and were selected by officers from a dropdown list, and were the fields queried for animal names, along with the descriptive narrative. This SQL query used the following key words to find animals within the narratives: "COYOTE", "COYOTES", "BURRO", "BURROS", "DONKEY", "MULE", "CATTLE", "COW", "COWS", "DEER", "HORSE”, "HORSES", "BEAR", "ANTELOPE", "BIG HORN SHEEP", "SHEEP", "ELK", "ANIMAL". This query also resulted in returns of all crashes where officers may have placed the name of a business with an animal name, a road with an animal name, and vehicles that contained animal names. To select out these extraneous records, Mr. Gonzales used a Python software script (Table 54) to extract the animal name and the surrounding words to determine if the record included a real animal involved in the crash.

The NDOT maintenance reported carcass database for 2006-2015 was also compiled and cleaned up by NDOT’s Mr. Gonzalez and Mr. Bacon, and delivered to the research team.

The resulting ten-year animal-related crash database from 2006-2015 was also translated into a shape file by NDOT. Both the database and shape file were delivered to the researchers.

The panel was interested in mapping all fatal crashes where the vehicle left the road or rolled over that may have been the results of an animal in the road, but no witnesses were able to describe the cause to law enforcement. The researchers queried all of the crash data and selected for fatal crashes that did not report an animal was involved. First, all crashes that involved a rollover event and the driver was killed were selected. Rollovers were filtered by querying the V1_SEQ_EVENTS or V2_SEQ_EVENTS fields for 'OVERTURN/ROLLOVER'. With this list, fatalities were then queried from CRASH_SEVERITY_DESC using 'FATAL CRASH.' The resulting database were all fatal roller events. Second, a subset of all crashes was created by querying the V1_SEQ_EVENTS or V2_SEQ_EVENTS fields for all 'RAN OFF ROAD RIGHT' or 'RAN OFF ROAD LEFT'. With this list, fatalities were then queried from CRASH_SEVERITY_DESC using 'FATAL CRASH.' The resulting database were all fatal "ran off the road" events.

All of the resulting crash and carcass databases from the above NDOT queries were used for statistical calculations and the creation of maps.

Table 54. Python Script Developed by Jason Gonzales of NDOT to Process Crash Data to Find Mention of All Types of Animals in the Narrative Sections of Reports.

```
import pandas as pd
import numpy as np

df = pd.read_excel("C:\Users\h9816jxg\Desktop\Wildlife Project\Wildlife
Processing\NarrativeTable.xlsx")

record_count = range(0, len(df.index))
print(record_count)

# Adds new fields to be populated
df['AnimalType'] = ""
df['AnimalString'] = ""


def string_processing():
    for row in record_count:
        acc_num = df.iloc[row]['ACCIDENT_NUM']
        mystring = df.iloc[row]['NARRATIVE']

        split_mystring = mystring.split()

        animal_list = ["COYOTE", "COYOTES", "BURRO", "BURROS", "DONKEY", "MULE",
"CATTLE",
                   "COW", "COWS", "DEER", "HORSE", "HORSES", "BEAR", "ANTELOPE",
                   "BIG HORN SHEEP", "SHEEP", "ELK", "ANIMAL"]

        sub_string = np.array(split_mystring)

        print(acc_num)

        for i in animal_list:
```

```
        if i in split_mystring:
            # Returns position of keyword within the string.
            found = split_mystring.index(i)
            # Creates start point for substring.
            a = found - 3
            if a < 0:
                if a == (-3):
                    a = found
                if a == (-2):
                    a = found - 1
                if a == (-1):
                    a = found - 2

            # Creates end point for substring.
            b = found + 4
            if b > len(split_mystring):
                b = found + (len(split_mystring) - found)
            # Total range for substring
            num_range = range(a, b)

            df.set_value(row, 'AnimalType', sub_string[found])

            narr_string = list(sub_string[num_range])
            df.set_value(row, 'AnimalString', ' '.join(narr_string))

string_processing()

writer = pd.ExcelWriter("C:\Users\h9816jxg\Desktop\Wildlife Project\Wildlife
Processing\ProcessedTable.xlsx",
                        engine='xlsxwriter')

df.to_excel(writer, sheet_name="NarrativeComplete")

writer.save()
print("Done")
000
```

Maps of Crash and Carcass Data

Ten years (2006-2015) of animal-related reported crashes and animal carcasses data were used to create shape files representing: total animal-related reported crashes; all carcasses reported; combined animal-related crashes and carcasses; and statewide maps of locations of crashes that involved each animal type. The individual animal type maps were created by querying the ‘first harm event,’ and ‘most harm event’ columns of the database for the various animal names listed above in the NDOT queries.

The research team used the crash and carcass data provided by NDOT to map the locations of crashes and carcasses of the top nine species of animals involved in vehicle accidents in Nevada, 2006-2015. The mapping process included:

1. Using the database, WildlifeData.gdb, data were extracted from the CrashData and CarcassData feature classes.
2. Within both feature classes (CrashData and CarcassData), the data were queried to extract crashes and carcasses for nine animals of interest (i.e. Deer, Cattle, Horse, Coyote/Dog, Elk, Burro, Pronghorn Antelope, Bear, and Bighorn Sheep).
3. Query of CrashData feature class:
    - Although it appears that the field ANIMAL_TYPE was generated to sum up all crashes involving wildlife, several fields within the attribute table of the CrashData feature class were queried to ensure that all crashes were captured. Previous queries that solely used the ANIMAL_TYPE field indicated that a few crash points were absent.
    - The fields FIRST_HARM EVENT, V1_SEQ_EVENT1, V1_SEQ_EVENTS V2_SEQ_EVENTS, and ANIMAL_TYPE were queried.
    - Example query: FIRST_HARM_EVENT = 'ANTELOPE' OR V1_SEQ_EVENT1 = 'ANTELOPE' OR V1_SEQ_EVENTS = 'ANTELOPE' OR V2_SEQ_EVENTS = 'ANTELOPE' OR ANIMAL_TYPE = 'ANTELOPE'
    - Any discrepancies between fields were evaluated to determine accuracy of point (i.e. comments were read and fields were compared).
4. Query of CarcassData feature class:
    - There is only one field within the CarcassData feature class that is relevant.
    - The field AnimalType was queried.
    - Example query: AnimalType = 'Antelope'

Once these data points were mapped, researchers created maps in the second quarter of 2017 that were most appropriate for display for NDOT needs. County names were included in the maps, and crash and carcass data were presented on a single map for each species.

GIS data were processed, which included sub-setting to Nevada state boundaries (if needed) (Figure 63), verifying and applying the appropriate coordinate system/projection (UTM Zone 11N, NAD83, meters), and development of an appropriate project-related data filing system.

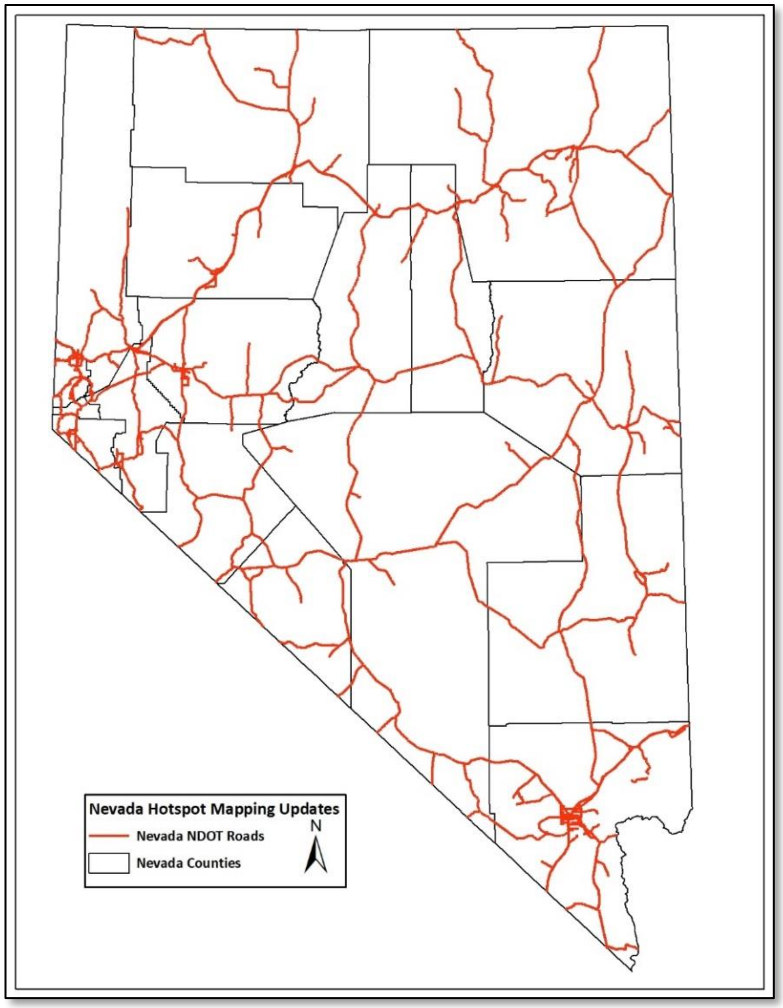

Figure 63. Nevada DOT Roads Data.

NDOT roads data were processed using the "dissolve" function. The dissolve function removes line intersection vertices and creates a single vector dataset independent of tabular (attribute) data. The dissolve function was applied twice, creating two independent datasets. The first file created from the dissolve function combined all 9,953-road vectors into a single line, thereby removing all unique attribute data. A second application of the dissolve function to the Nevada DOT Roads layer dissolved the features into multi-part vectors summarized by ROAD_NAME. This file resolved the 9,953-road vectors into 1,416 features, or uniquely identified road names. The dataset contained no unnamed road vectors. The dissolve results will be used to create a divided buffer by which vehicle crashes, wildlife-involved vehicle collisions, and recorded wildlife carcass data can be spatially evaluated for evidence of hotspots.

Roads data was buffered using the ArcGIS Geoprocessing Buffer Wizard. The dissolved roads layers were buffered to 200 feet (60.96m). This distance was selected to ensure that carcass, crash, and wildlife vehicle collision data that may spatially occur on collector ramps, frontage roads, or slightly beyond the immediate roadway area, would be captured in the later hotspot analyses.

APPENDIX B. LITERATURE REVIEW

Introduction

The literature review is presented in two parts: State efforts to map wildlife-vehicle collisions and carcasses, and articles, books, websites, and reports pertinent to this study.

Methods

The review of the state efforts was investigated during previous research and during this research by reaching out to colleagues in western and several eastern states to investigate results of current research projects, workshops, and efforts to deal with wildlife-vehicle conflict. The references presented were taken from previous research, a search of the Transportation Research Board's TRID searchable database for past papers and reports and ongoing studies from early 2017 back into the fall of 2014, attendance at the 2017 Transportation Research Board's Annual meeting, and interviews with colleagues in Colorado, Montana, California, Arizona, New Mexico, Georgia, and Florida.

Results of States' Efforts to Collect and Map Wildlife-Vehicle Collision Crashes and Carcasses, to Map Wildlife Linkages, and to Create Prioritization Processes

To best identify wildlife-vehicle conflicts and then prioritize appropriate actions, states typically undertake four steps: collect crash and carcass data, map WVC carcass and crash data, identify hypothetical or real wildlife linkages (depending on data used), and create a standardized prioritization methodology for wildlife mitigation actions. This section presents how U.S. Western states undertake those steps. Most states have not completed every step. Idaho and Washington are standardizing and continually updating these processes. Other states, such as Wyoming and Utah, have some of these steps, but because their DOT staff have access to creating maps as necessary, and have good working relationships with wildlife agency personnel, statewide maps and standardized procedures have not been considered a priority and have not been created. Other states such as Montana and Colorado have ongoing projects in 2018 to create standardized processes for the DOT agency personnel to follow for future priority actions. Table 55 gives an overall summary of these state efforts. Greater detail can be found in Cramer et al. (2016), and Cramer et al. (2014).

The options for collecting carcass data range in a spectrum from paper data sheets filled out in the field to smart phone apps with instant uploads to an internet mapping site. Since the future is either smart phone and tablet apps, or websites accessed by phones, tablets, or computers, these two options would be the ones most recommended for NDOT to pursue. Several states have created smart phone apps; applications useable on mobile devices i.e. smartphones and tablets. Utah's DOT and wildlife agency were the first agencies to create and adopt a smartphone app that uses a browser to automatically upload data to a web application for staff use (see Olson et al. 2015 for reference). This code is available to other states to adapt for their locations. Arizona is in the alpha stage of testing their carcass smart phone app. Washington has software for carcass collection on maintenance worker IPads, which are then uploaded to the WSDOT workbench on-line. South Dakota created a proto-type smart phone carcass app and will be testing it later in 2017. California's and Maine's systems are similarly available to smartphones through a web-browser application accessed on the phone, and in 2017 will also have a cross-platform app that can upload to any state's or country's system.

The more common method for reporting carcasses is through a website accessed with computers. Web-based applications were first made available to the public in California and Maine in 2010 (Shilling and Waetjen 2015), through the University of California at Davis, Road Ecology Center. Users can upload carcass data and photos. Idaho Game and Fish Department has a website developed in conjunction with Idaho Transportation Department, see Idaho in table below. The Idaho site allows for information upload (no photos) and downloads. These sites are beneficial in that they allow anyone to map carcasses on-line at any time and with different filters. All systems require software upgrades on a monthly to annual basis. Overall, immediate electronic upload of data, with a Global Positioning System (GPS) location is the future of carcass collection.

Results are summarized in Table 55 below.

Table 55. States' Efforts to Collect and Map WVC Data, Wildlife Linkages Maps, and Prioritization Processes.

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
Arizona	No standard protocol, AZDOT maintenance	None	Premier state effort. URL: https://www.azdot.gov/docs/planning/arizona_wildlife_linkages_assessment.pdf?sfvrsn=7 See Arizona Wildlife Linkages Working Group in References.	Dodd 2014, see references. Created a score card, GIS info, AADT, % of crashes that are WVC, species maps. Not known how to what extent it is used.
California	Caltrans Maintenance – sporadic, not uniform reporting. Also, UC Davis Road Ecology Center's California Roadkill Observation System, URL: http://www.wildlifecrossing.net/california/. REC. Dr. Shilling negotiating contract with Caltrans to standardize data collection, reporting, and analyses.	No statewide effort. Carcasses (2009-2017) and WVC (2015-2017) mapped by UC Davis Road Ecology Center.	Several different efforts. See California Dept. of Fish and Wildlife Site: https://www.wildlife.ca.gov/Conservation/Planning/Connectivity	No standardized Process.

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
Colorado	Maintenance workers collect carcasses and data, compliance voluntary, thus not uniform.	See Crooks et al. in references. URL: http://warnercnr.colostate.edu/~sharonbm/docs/CDOTconnectivityfinalreport.pdf	2005 Effort, Linking Colorado's Landscapes. URL: http://rockymountainwild.org/linking-colorados-landscapes There is a current project underway in 2017.	None, but a 2017-18 research project was underway to create a process.
Idaho	Maintenance workers collect carcasses and data, input into state system. Public inputs carcass data in open website: URL: https://fishandgame.idaho.gov/species/roadkill	Mapping of carcasses can be done in real time via the website. Crash mapping can be done by agency personnel on IPLAN website, a planning tool. Cramer et al. 2014 created static map.	Workshops in 2005 and 2007 resulted in linkage maps: https://fishandgame.idaho.gov/ifwis/portal/opendata/idaho-highway-wildlife-linkages Reference: Inghram et al. 2009.	First State to create standardized prioritization. See Cramer et al. 2014 in references. URL: http://idahodocs.cdmhost.com/cdm/ref/collection/p16293coll3/id/251412
Montana	Maintenance workers collect carcasses and data. Somewhat compliant compared to other states, but still spotty.	Mapping can be done by MDT personnel, with their ArcGIS tools on their desks.	Montana Fish, Wildlife & Parks, Crucial Areas Planning System (CAPS): http://fwp.mt.gov/fishAndWildlife/conservationInAction/crucialAreas.html	Currently, every 2 years MDT meets with MT Fish Wildlife and Parks to review STIP. Current research project underway in 2018 to standardize state planning for wildlife.
Nebraska	No systematic method to collect carcass data	No known maps, but a Deer-Vehicle Information Kit	None	None, mostly ESA and Nebraska law requirements are the only time wildlife are considered.

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
		available for county tables of intensity of deer-vehicle crashes: URL: http://roads.nebraska.gov/media/6502/dvcinformationkit.pdf		
Nevada	Maintenance workers collect data, has been inconsistent, but it is hoped new reporting requirements hope to rectify.	In 2010 Chris Wright created statewide map of WVC crash plus carcass data (see map in this document).	The non-profit Nevada Wilderness Project identified 20 wildlife linkages, but not easily found on web anymore.	The role of this study.
New Mexico	Maintenance workers gather data. NM house Memorial 1 established that NMDOT and NM Game and Fish look into establishing a citizen monitoring program for carcass data.	2003 priority map was created. Not available on internet at this time, but was in past.	Multiple concurrent state efforts, but no official map. December 2016 Upper Rio Grande Wildlife Connectivity Workshop is most recent and most science-based effort. URL: https://nhnm.unm.edu/Wildlife_Movement_Workshop. Also see Muldavin and McCollough in references.	House Joint Memorial 10, in 2012 dictated many actions to reduce WVC, but did not find proof of compliance. URL: https://www.nmlegis.gov/lcs/handouts/WNR%20101512%202.%20HJM%2010%20Report%20Final_June20%202012.pdf

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
Oregon	Maintenance workers fill out forms for carcass collection. Not sure of statewide accuracy.	Created static map in 2007, see: ftp://ftp.odot.state.or.us/techserv/Geo-Environmental/Webs/Wildlife_Movement/Wildlife/wchs.htm. See Trask in references.	Oregon Dept. of Fish and Wildlife and Oregon DOT worked together w/ others on the Oregon Wildlife Movement Strategy: https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx?p=202&XMLname=806.xml	None statewide.
South Dakota	Contractors hired jointly by SDDOT and SD Game and Fish fill out forms. IN 2017 created a smartphone app with Survey123 software, now in use. Map available: http://sdgfp.maps.arcgis.com/apps/webappviewer/index.html?id=268318a624ec4228a73e22f297d9f27e	Crash and carcass data mapped in 2016, Cramer et al. 2016. No other efforts since then. Cramer recommended future annual mapping.	No efforts.	Cramer et al. 2016 recommended creating a process in the future. None at this time.
Texas	No statewide method to report carcass data.	None	None	A forthcoming research project in 2018 will be addressing all these concerns within TXDOT.

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
Utah	Contractors required to upload data to Carcass Phone app.	Wildlife vehicle collision reporter uploads carcass data points immediately to protected website, and anyone with access can at any time map WVC carcass data: URL: https://mapserv.utah.gov/wvc/desktop/	None, Cramer proposed initial plan to UDOT in March of 2017. Utah Division of Wildlife Resources started a wildlife migration initiative in 2017 which may lead to linkage maps.	No standard statewide, except for Utah Division of Wildlife Resources habitat managers meeting annually with UDOT representatives to review upcoming projects and make recommendations. UDOT-Cramer research project to help standardize this, in 2018-19.
Washington	Maintenance workers record carcasses on Ipads that were placed into service in 2015.	No official map because WSDOT personnel have access to the data through the intra-agency Environmental Workbench which allows them to map WVC crash and carcass data as needed.	Washington Wildlife Habitat Connectivity Working Group identified priority wildlife linkages: http://waconnected.org/statewide-analysis/	The Habitat Connectivity Investment Priorities Method was developed in WSDOT by K. McAllister. The method is still being accepted and worked into WSDOT practices across the state.
Wyoming	Maintenance crews collect carcasses and data. Reports submitted to be	WYDOT Highway Safety Program produces maps upon request. No	None statewide. WYDOT uses different data sources to bring data together, such as WY	No formal process. WY Game and Fish and WYDOT have close working relations.

State	Carcass Collection Protocols	Carcass or Crash Mapping	Wildlife Linkage Mapping	Planning and Prioritization Process
	entered into state database. Variability in compliance.	state-wide WVC map at this time.	Interagency Spatial Database and Online Management System (WISDOM), WY Game and Fish data, etc.	
Western Governors' Association			Crucial Habitat Assessment Tool: http://www.westgov.org/wildlife-corridors-and-crucial-habitat and http://www.wafwachat.org/	

Literature Search References

References are presented according to topic area: mapping wildlife-vehicle collisions, carcass reporting apps, projects to prioritize wildlife-vehicle conflict areas, wildlife connectivity, benefit-cost in transportation, wildlife-vehicle collision prevention methods such as animal detection systems, and finally, overall important papers.

Papers on Mapping Wildlife-Vehicle Collisions

There were four important papers that helped to inform this study with respect to mapping wildlife-vehicle collisions. Those papers are listed below.

Kociolek, A., L. Craighead, A. Craighead. 2016. Evaluating wildlife mortality hotspots, habitat connectivity, and potential mitigation in the Madison Valley. Final Report to Montana Department of Transportation. FHWA/MT-16-016/8217-001.

McClure, M. and R. Ament. 2014. Where people and wildlife intersect: prioritizing mitigation of road impacts on wildlife connectivity. Center for Large Landscape Conservation. URL: http://largelandscapes.org/media/publications/Where-People--Wildlife-Intersect-Prioritizing-Mitigation.pdf

Shilling, F. M. and D. P. Waetjen. 2015. Wildlife-vehicle collision hotspots at US highway extends: scale and data source effects. Nature Conservation 11:41-60. Doi:10.3897/natureconservation.11.4438.

Visintin, C. R. van der Ree, and M. A. McCarthy. 2016. A simple framework for a complex problem? Predicting wildlife-vehicle collisions. Ecology and Evolution. Published by John Wiley and Sons, Ltd. Doi:10.1002/ece3.2306

Other Wildlife-Vehicle Collision Hotspot Mapping Papers, Book Chapters, and Reports

Clevenger, A. P., B. Chruszcz, K. Gunson. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109:15-26.

Garrah, E., R. K. Danby, E. Eberhardt, G. M. Cunnington, and S. Mitchell. 2015. Hot spots and hot times: wildlife mortality in a regional conservation corridor. Environmental Management, 56:874-889. Doe 10.1007/s00267-015-0566-1.

Gibby, A. R., and R. Clewell. 2006. Evaluation of wildlife warning systems and other countermeasures. Report to Nevada Department of Transportation and the Federal Highway Administration. Report Number NV-RDT-060010. 44 pages.

Green, D. A., P.C. Cramer, D.K. Sakaguchi, N.H., Merrill. 2011. Using wildlife-vehicle collision data to plan and implement transportation mitigation: case studies from Utah. In: Proceedings of the 2011 International Conference on Ecology and Transportation, Seattle, WA, Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. URL: http://www.icoet.net/ICOET_2011/documents/proceedings/Session-COM-1.pdf

Gunson, K. E., A. P. Clevenger, A. T. Ford, J. A. Bissonette, and A. Hardy. 2009. A comparison of data sets varying in spatial accuracy used to predict the occurrence of WVC. Environmental Management, 44:268–277.

Gunson, K. E., D. Ireland, and F. Schueler. 2012. A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in Southern Ontario, Canada. *North-Western Journal of Zoology,* 8(2) Article No. 121401.

Gunson, K. E., and F. Z. Teixeira. 2015. Identifying the patterns and processes of wildlife road interactions are important to inform road-wildlife mitigation planning, in R. van der Ree, D. J. Smith, and C. Grilo, editors. Handbook of Road Ecology. John Wiley & Sons, Oxford.

Hothorn, T., R. Brandl, and J. Muller. 2012. Large-scale model-based assessment of deer-vehicle collision risk. PLoS ONE 792): e29510. Doi: 10.1371/journal.pone.0029510.

Olson, D., J. Bissonette, P. Cramer, K. Bunnel, D. Coster and P. J. Jackson. 2014b. Vehicle collisions cause differential age and sex-specific mortality in mule deer. Advances in Ecology, 2014, Article ID 971809. URL: Http://dx.doi.org/10.1155/2014/971809

Patrick, D. A., J. P. Gibbs, V. D. Popescu, and D. A. Nelson. 2012. Multi-scale habitat-resistance models for predicting road mortality “hotspots” for turtles and amphibians. Herpetological Conservation and Biology, 7:407–426.

Snow, N. P, W. F. Porter, and D. M. Williams. 2015. Under-reporting of WVC does not hinder predictive models for large ungulates. Biological Conservation, 181:44-53.

Papers, Reports, Websites on Reporting Wildlife-Vehicle Collision Carcasses with Apps and Websites

Donaldson, B. and N. Lafon. 2008. Testing an integrated PDA-GPS system to collect standardized animal carcass removal data. Virginia Transportation Research Council. URL: http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-cr10.pdf

Jacobsen, M. 2014. Road-kill app paints clearer picture of WVC. *Desert News*. URL: http://www.deseretnews.com/article/865607995/Roadkill-app-paints-clearer-picture-of-wildlife-vehicle-collisions.html?pg=all

Olson, D. 2013. Assessing vehicle-related mortality of mule deer in Utah. PhD Dissertation, Graduate School of Utah State University. Paper 1994. URL: http://digitalcommons.usu.edu/etd/1994.

Olson, D. D., J. A. Bissonette, P. C. Cramer, A. D. Green, S. T. Davis, P. J. Jackson, and D. C. Coster. 2014a. Monitoring WVC in the information age: how smartphones can improve data collection. *PLoS ONE*, 9(6): e98613. DOI:10.1371/journal.pone.0098613

Tetra Tech EBA. 2016. Wildlife Watch App for improved road safety in Alberta. TAC Environmental Award submission, February 15, 2016.

University of California Davis Road Ecology Center. 2017. California Roadkill Observation system (CROS). URL:http://wildlifecrossing.net/california

Papers and Reports on Projects to Prioritize Wildlife-Vehicle Collision Areas State-Wide

Cramer, P., J. Kintsch, K. Gunson, F. Shilling, C. Chapman. 2016. Reducing wildlife-vehicle collisions in South Dakota, Final Report to South Dakota Department of Transportation, SD2014-03, Pierre, SD.

Cramer P.C., S. Gifford, B. Crabb, C. McGinty, D. Ramsey, F. Shilling, J. Kintsch, S. Jacobson, and K. Gunson. 2014. Methodology for Prioritizing Appropriate Mitigation Actions to Reduce Wildlife-Vehicle Collisions on Idaho Highways. Idaho Transportation Department, Boise, Idaho. August, 2014. URL: http://idahodocs.cdmhost.com/cdm/ref/collection/p16293coll3/id/251412

Crooks, K., C. Haas, S. Baruch-Mordo, K. Middlefor, S. Magle, T. Shenk, K. Wilson and D. Theobald. 2008. Roads and connectivity in Colorado: Animal-vehicle collisions, wildlife mitigation structures, and lynx-roadway interactions. Final report to Colorado Department of Transportation. 187 pages. URL: http://warnercnr.colostate.edu/~sharonbm/docs/CDOTconnectivityfinalreport.pdf

Dodd, N. 2014. State-wide wildlife crash analysis and proposed action plan. Arizona Department of Transportation. 24 pages.

Meyers, W.L., W.Y. Chang, S.S. Germaine, W.M. Vander Haegen, and T.E. Owens. 2008. An analysis of deer and elk-vehicle collision sites along state highways in Washington State. A report to the Washington Department of Transportation, Olympia, Washington. 33 pages. URL: http://www.wsdot.wa.gov/research/reports/fullreports/701.1.pdf

Muldavin, E. and R. McCollough. 2016. Wildlife doorways: Supporting wildlife habitat connectivity across borders in the upper Rio Grande watershed. Natural Heritage New Mexico Publication No. 16 – GTR-394.

Nichols, A. P., M. P. Huijser, R. Ament, S. Dayan, and A. Unnikrishnan. 2014. Evaluation of deer-vehicle collision rates in West Virginia and a review of available mitigation techniques. Report to the West Virginia Department of Transportation. Charleston, WV.

Ruediger, B., P. Basting, D. Becker, J.Bustick, P. Cavill, J.Claar, K. Foresman, G. Hieinz, D. Kaley, S. Kratville, J. Lloyd, M. Lucas, S. McDonald, G. Stockstad, J. Vore, K. Wall, and R. Wall. 2004. An assessment of wildlife and fish linkages on Highway 93 - western Montana. USDA Forest Service, USDI Fish and Wildlife Service, confederated Salish and Kootenai Tribe, Rocky Mountain Elk Foundation, Montana Fish, Wildlife and Parks, Montana Department of Transportation, Geodata Services, The University of Montana, Forest Service Publications #R1-04-81, Missoula, MT. 41 pp.

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Papers, Books, and Reports on Wildlife Connectivity

Arizona Wildlife Linkages Workgroup. 2006. Arizona Wildlife Linkages Assessment. Arizona Department of Transportation and Arizona Game and Fish Department. URL: https://www.azdot.gov/docs/planning/arizona_wildlife_linkages_assessment.pdf?sfvrsn=7

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APPENDIX C. IDAHO MEMORANDUM OF UNDERSTANDING FOR WILDLIFE-VEHICLE COLLISION COLLABORATION

PURPOSE: MEMORANDUM OF UNDERSTANDING
Between THE IDAHO TRANSPORTATION DEPARTMENT
And
THE IDAHO DEPARTMENT OF FISH AND GAME

This MEMORANDUM OF UNDERSTANDING (MOU) is hereby made and entered into by and between the Idaho Transportation Department, (hereinafter "ITD"), and the Idaho Department of Fish and Game, (hereinafter "IDFG"), collectively referred to as the "parties." Both parties acknowledge that:

1. The collaboration and processes outlined in this MOU are designed to enhance the efforts of the agencies within their ordinary regulatory and statutory obligations.

2. Traditional project-by-project evaluation and coordination limit the effectiveness for the signatory agencies in achieving their missions.

3. Enabling safe wildlife passage, reducing road kill, and increasing public safety at the earliest opportunities, particularly in locations where regulatory processes do not require wildlife mitigation or conservation measures, will require financial support from both the agencies and other partners.

4. Resources devoted to regulatory consultation and documentation on a project-by project basis, in many cases, would be better spent on combining and streamlining processes and data for multiple projects, plans, and programs over an extended timeframe. This economy of scale would allow a coordinated program to address habitat fragmentation, wildlife viability, and transportation planning and development at the statewide level.

BACKGROUND:
The ITD's mission is to promote safety, mobility, and economic opportunity for users of Idaho’s transportation system. The IDFG's mission is to preserve, protect, perpetuate and manage the fish and wildlife populations of the State. It is for the economic, social, cultural, and recreational benefit of Idaho’s citizens and visitors that IDFG and ITD collaborate for the common purpose of maintaining and improving Idaho's transportation systems while simultaneously protecting and managing the Idaho's fish and wildlife resources and their associated habitats. This MOU embodies the idea that "we cannot sacrifice transportation for wildlife and we cannot sacrifice our wildlife for transportation" and so establishes a program of cooperation between the agencies.

AUTHORITY:
This MOU is entered into pursuant to the authority of Idaho Code, Chapter 23, Title 67, Sections 2326 through 2333 and 2339 (Joint action by public agencies), and 40-309 (Transportation Board powers and duties). This MOU supersedes the previous MOUs signed in March 1987, January

1993, and April 2004, but does not invalidate MOUs written between ITD districts and IDFG regions.

SPECIFIC AREAS OF COLLABORATION:
Data Access and Information Systems

ITD SHALL:

1. Automatically, on no less than a monthly basis, export all road kill data from TAMS to IDFG for incorporation into their road kill and observations database.

2. Automatically, on no less than a monthly basis, export all law enforcement reported wildlife vehicle collisions to IDFG for incorporation into their road kill and observations database.

3. Respond to individual requests from IDFG for transportation system information within 2 weeks unless otherwise coordinated. For re-occurring requests, provide the data via the most effective means of electronic data transfer.

4. Annually update the wildlife vehicle collision risk map using the protocol and data identified in wildlife vehicle collision research in Methodology for Prioritizing Appropriate Mitigation to reduce Big Game Animal-Vehicle Collisions on Idaho Highways (P. Cramer et al 2014) or the most recently accepted protocol.

IDFG SHALL:

1. Maintain and develop databases, applications, and web services or some other means of effective electronic data transfer for purposes of data exchange with ITD. This data shall be credible for transportation planning and project assessment purposes. Site specific knowledge and consultation as well as ongoing data collection will need to come from regional staff.

2. Provide real time access to updated fish and wildlife data including threatened, endangered, game, and species of greatest conservation need including wetlands, waters, priority areas, areas of connectivity, and other associated data that are pertinent to the planning and maintenance of the transportation system. Respond to individual request for information within two weeks unless otherwise coordinated.

3. Provide interpretation of IDFG data regarding its appropriate application, when requested or needed.

Both Parties SHALL:

Establish a Data Development Team by August 2015 as outlined in Exhibit A.

Professional Services

ITD SHALL:

Consider the expertise of the IDFG personnel for contract services related to federal requirements for biological assessments, designing and implementing monitoring and surveys, and providing consultation associated with state and federal highway projects within available resources and desired timelines. Development of professional service agreements on an annual basis are encouraged. See Exhibit B for a Cooperative Agreement template for single or multiple projects. ITD shall consider use of Best Management Practices recommended by IDFG within available resources.

IDFGSHALL:

Consider the expertise of the ITD personnel for contract services related to engineering and traffic control functions associated with fish, wildlife, and administrative projects within available resources and desired timelines. Development of professional service agreements on an annual basis are encouraged. See Exhibit B for a Cooperative Agreement template.

Provide current and applicable Best Management Practices and designs for fish and wildlife treatments and modifications related to transportation systems at annual meetings or as part of normal project review. These treatments and designs will be the most current and accepted for transportation systems and will provide engineering specifications as available.

Both Parties Agree:

To evaluate the potential sharing of human resources and expertise for mutual benefit. Such human resources might include technical personnel, biologists, engineers, planners, and project specialists. Sharing might consist of either agency providing some or all of either a full-time employee or associated salary with a specific work plan and clearly outlined supervisory lines and work objectives.

Project Communication and Coordination

Both Parties SHALL:
I. District/Region: Meet annually, between March and June, to discuss issues of mutual concern. See Exhibit C for recommended attendees and typical agenda items. The designated ITD and IDFG meeting note keepers will copy the ITD Environmental Section Manager and IDFG Wildlife Program Coordinator, respectively.

2. Headquarters: Meet annually, between March and June, to discuss issues of mutual concern and assure the MOU is operationalized. Provide annual updates to their respective Director's offices on the implementation and success of this MOU.

3. Respond to information and input requests from the other agency within two weeks of the request unless otherwise notified.

4. Consider comments from the other agency when developing project scope and budget.

5. Continue with currently established and functional coordination meetings, as needed.

Public and Media Relations

Both Parties SHALL:

I. When issuing a press release which may impact or affect the other agency, the affected agency will be given advance notice and provided an opportunity to offer input on the draft press release, before it is released to the public.
2. Cooperate in the issuance and/or development of joint statements, press releases, website content, collaboration, and success stories when the issue or topic includes mutual areas of concern, interest, and investment.

3. When contacted by the media about an issue or topic that includes mutual areas of concern, interest, and investment, staff will take the following steps: 1) Inform superiors and make certain of messages to be conveyed before responding. 2) Insure adherence to agency media/public information policies. 3) Contact the other agency prior to or immediately after conducting a media interview and provide them the media contact information. 4) Suggest the media contact the other agency for their perspective on the given topic.

Road-killed Big Game animals:

ITD SHALL:

I. Report all road-killed big game animals to the nearest 1/10th of a mile in the TAMs database no less than bi-weekly.

2. In coordination with Regional IDFG Staff, encourage the reporting of road killed wildlife species other than big game, especially where road kill frequency or type may be indicating an important conservation or resource issue.

IDFG SHALL:

I. Report all road-killed big game animals observed to be reported to the nearest 1/10th of a mile in the IDFG road kill web application no less than bi-weekly. <https ://fishandgame.idaho. gov/species/roadkill>

2. Use road kill data for purposes of mapping and prioritizing wildlife crossings, linkages, and public safety concerns. Develop collaborative highway treatment plans and funding to reduce road kill, increase wildlife linkage/connectivity/corridors, and reduce hazards to drivers.

3. Communicate and develop road kill information for wildlife species and conservation priorities in relation to listed, greatest conservation need, and locally important species.

Both parties SHALL:

1. Develop a cooperative ITD District-IDFG Region Road Kill Removal and Disposal Protocol.

2. Remove big game or any road-killed species that presents a potential safety hazard from the roadway upon first encounter.

3. Dispose of Big Game road-killed animals in a manner that is consistent with public health and safety concerns.

4. Report any identified federally protected road-killed species to the U.S. Fish and Wildlife Service and/or IDFG. These may include eagles, grizzly bears, and lynx.

Signage and Public access

ITD SHALL:

1. Develop and deploy signage to clearly identify and delineate public recreation access.

2. Install and maintain authorized Wildlife Management Area (WMA) permanent wildlife management signs and other fish and game guide signs at IDFG expense.

3. Provide to IDFG a list of surplus properties that may be exchanged, sold, or donated to IDFG for the enhancement of public access and recreation.

IDFG SHALL:

1. Develop and deploy signage to clearly identify and delineate public recreation access.

2. Provide to ITD an inventory of surplus properties that may be exchanged, sold, or donated to ITD for the enhancement of transportation systems.

3. Provide to ITD an updated inventory of IDFG properties where public recreation and access may be developed and provided in cooperation with
ITD.

Both Parties SHALL:

1. Discuss the above in the context of district/region cooperation through their participation in and according to the identified structure in Exhibit C. Develop funding opportunities and cooperatively fund development and enhancement of public recreation and access opportunities.

2. Coordinate additional signage, as agreed.

LIMITATIONS:
Nothing in this MOU by and between ITD and IDFG shall be construed as limiting or expanding the statutory or regulatory responsibilities of either agency or any involved individual acting on behalf of the agency or in performing functions granted to them by law; or as requiring either agency to expend any sum in excess of its respective appropriation. Each and every provision of this MOU is subject to the laws and regulations of the state of Idaho and of the United States.

Nothing in this MOU shall be construed as expanding the liability of either party. In the event of a liability claim, each party shall defend their own interests. Neither party shall be required to provide indemnification of the other party. This MOU does not in any way restrict any entity from participating in similar activities with other public or private agencies, organizations, and individuals.

EFFECTIVE DATE:
This MOU shall become effective upon signature of the Director of ITD and the Director of IDFG.

METHOD OF TERMINATION:
This MOU shall remain in force for five years from the date of the last signature unless it is mutually extended or formally terminated by either party after thirty (30) days written notice to the other party.

AMENDMENTS:
Amendments to this MOU shall become effective upon the date of mutual agreement and written approval by the Director of lTD and the Director of lDFG.

IDAHO TRANSPORTATION DEPARTMENT
Director

IDAHO DEPARTMENT OF FISH AND GAME
Director

Exhibit A

Data Development Team Agenda

Wildlife Program Coordinator

Recommended Frequency: Semi-annually. As needed follow up meetings, outside of this structure, should take place if issues and discussions arise.

Duration: Approximately 2 hours

Location: Alternate annually between ITD and IDFG HQ facilities

Responsible party for organization of meeting and agenda: IDFG Program Coordinator and ITD Environmental Services Manager

Considerations:

• Plan ahead - Schedule the meeting at least two months prior to proposed date to ensure participation from all parties

• Take good notes -consider designating a note taker

Topics to discuss:

• Identify a process for what new data will be collected, how it will be collected and the process for developing the tools

• Create a clause regarding the standard for acceptance of sister agencies' data

• Work towards 24/7 data access between agencies

• Provide for a project milestone "checklist" to ensure data sharing and resulting actions occur

• Address staffing issues

• Work towards data sharing online as much as possible, particularly with existing resources (e.g. ITD Planning Network (IPLAN), Crucial Habitat Assessment Tool (CHAT), etc.)

• Challenges associated with interpretation/explanation of data and any restrictions on its use

• Identify the lifespan of data

• Set a timeframe for providing official responses between agencies

Tracking Progress

• Send out notes to all participants and upper-level management

• IDFG Program Coordinator and Environmental Section Manager to follow up every quarter with attendees on action items, issues and questions related to the above topics.

Exhibit B

TEMPLATE COOPERATIVE AGREEMENT FOR IDAHO DEPARTMENT OF FISH AND GAME
IDAHO TRANSPORTATION DEPARTMENT

PROJECT NO. AO ---
(Project Name)
(Key No.)
THIS Cooperative Agreement is made and entered into this day of __________ , , by and between the Idaho Transportation Department, hereafter called ITD and the Idaho Department of Fish and Game, hereafter called the IDFG.

PURPOSE
The purpose of this agreement is to use the expertise of IDFG staff to complete biological evaluations needed for ITD project development.
The work covered by this Agreement for Project No_____ is_____, as shown on the attached Exhibit A, Scope of Work.
The Parties Agree As Follows:

The IDFG agrees to:
1. Provide an estimate of the approximate cost, time and schedule for the work noted on Exhibit A.
2. Bill the ITD for reimbursement of actual expenses. IDFG will maintain complete records and submit an itemized invoice of all manpower, materials and out-of-pocket expenses, and accomplish all record-keeping in accordance with the following procedures:
a. Individual time sheets will be maintained reflecting the total hours spent on the project. It is imperative that the hours be traceable to the project.
b. Material - Costs of new material utilized on the project shall be supported by copies of invoices.
c. Out-of-pocket expenses - All expenses shall be supported by copies of receipts.
d. The record system will be such that all costs can be traceable from all billings through the ledgers and the source document.
3. Conduct all services using qualified personnel.
4. Deliver a monthly progress report to ITD unless otherwise noted in Exhibit A. The progress report shall include the status of budget and schedule, complete, and any potential changes to the scope of work.
5. Deliver the product within the schedule and budget noted in Exhibit A.
6. Deliver documents in a format shown in Exhibit A.

The ITD agrees to:
1. Provide additional information requested by IDFG in a timely manner.
2. Make all appropriate payments to IDFG, based on quarterly billing requests.

TERM OF AGREEMENT
This Agreement shall become effective on the first date written above and remain in full force and

effect until amended, replaced upon the mutual consent of the ITD and IDFG or performance of the above conditions are not being met satisfactorily by any party. Either party may terminate this Agreement upon written notice to the other signatory agency.

EXECUTION
This Agreement is executed for the ITD by its

District Engineer and executed for
IDFG by the Chief of the Bureau of Administration.

IDAHO TRANSPORTATION DEPARTMENT
District Engineer

IDAHO DEPARTMENT OF FISH AND GAME
Chief of Administration

APPENDIX D. TABLE OF GEOGRAPHIC INFORMATION SYSTEMS LAYER SOURCES

Table 56 below presents the geo-referenced data layers used in this research.

Table 56. Geographic Information Systems Data Gathered for This Research.

FOLDER	DESCRIPTION	FILE NAME	DATA SOURCE	SOURCE
Admin_Boundaries	County Boundaries	NV_County_Boundaries.shp	Nevada DOW	Email from Traffic Safety (NBacon@dot.nv.gov)
Admin_Boundaries	Land Ownership	NV_Land_Ownership.shp	Nevada DOW	Email from Traffic Safety (NBacon@dot.nv.gov)
Admin_Boundaries	State Boundaries	NV_State _Boundary.shp	Nevada DOW	Email from Traffic Safety (NBacon@dot.nv.gov)
Basemap_Data	Elevation (DEM)	mosaic_utm11n.img	The National Map	https://nationalmap.gov/
Basemap_Data	Places (Cities & Towns)	tl_2016_32_place.shp	United State Census Bureau	ftp://ftp2.census.gov/geo/tiger/TIGER2016/
Crash_Data	Crash Data Analysis	CrashDataAnalysis.gdb	Nevada DOT	Emailed through Traffic Safety contacts
NDOT_Data	County Boundaries	NV_COUNTIES.gdb	Nevada DOT	https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/engineering/location/geospatial-data
NDOT_Data	Milepost Makers	NV_MILEPOST_MARKERS.gdb	Nevada DOT	https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/engineering/location/geospatial-data
NDOT_Data	Roads	NV_ROADS.gdb	Nevada DOT	https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/engineering/location/geospatial-data
Road_Data	TRINA Roads	Trina_lines.shp	Nevada DOT	Email from Traffic Safety
	Average Annual Daily Traffic		Nevada DOT	Emailed through Traffic Safety contacts
Wildlife_Data	Crossings	NVWildlifeCrossings.gdb	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Mitigation	NVWildlifeMitigation.gdb	Nevada DOT	ftp://ftp.dot.state.nv.us/Public/WVC_Statewide_Assessment/

FOLDER	DESCRIPTION	FILE NAME	DATA SOURCE	SOURCE
Wildlife_Data	Wildlife Distribution (Bighorn Sheep Movement Corridors)	BighornSheep_MovementCorridors_2010.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Bighorn Sheep)	BighornSheep_Distribution_2016.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Black Bear)	Bear_Distribution_2009.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Elk)	Elk_Distribution_2013.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Fishable Lakes)	NDOW_Designated_Fishable_Lakes.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Mountain Goat)	MountainGoat_Distribution_2007.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Mule Deer Movement Corridors)	MuleDeer_MovementCorridors_2013.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Mule Deer)	MuleDeer_Distribution_2014.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Pronghorn Antelope Movement Corridors)	Pronghorn_MovementCorridors_2004.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Pronghorn Antelope)	Pronghorn_Distribution_2010.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Regions)	NDOW_Regions_Statewide.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife Distribution (Wildlife Management Areas)	NDOW_WildlifeManagmentAreas.shp	Nevada DOW	http://gis.ndow.nv.gov/ndowdata/
Wildlife_Data	Wildlife-Vehicle Conflicts	WildlifeData.gdb	Nevada DOT	Email from Traffic Safety

APPENDIX E. CRASH AND CARCASS HOT SPOT ANALYSES METHODS

These methods were carried out under Task 2, mapping hotspots for animal-vehicle crashes and carcasses collected along roadways across Nevada. The information is presented in a step-by-step manner to allow future identical iterations of this process.

Data Preparation

The Nevada Animal-Vehicle Crashes (AVC) and the Nevada Recorded Carcass Locations (RCLs) datasets were subset in multiple ways to answer questions posed by NDOW and NDOT. Data were initially sorted to provide a general view of crashes including fatal runoff crashes and fatal rollover crashes. These data were extracted using a series of attribute queries, and as guided by NDOT to understand the complexities of the attribute tables.

The AVC and RCL data was similarly prepared to display individual species using ArcGIS query builder. Multiple fields within each attribute table contained different fields that indicated the incident and type of species involved.

Hot spot analyses were conducted on both the AVC and RCL datasets. Prior to analysis, incidents involving horses, burros, and cows (HBCs) were removed from the dataset. These removals were done to better show the impact of critical *wildlife* species. The AVC dataset, with HBCs removed yielded a ten-year data set with 3,811-recorded incidents. The RCL dataset, with HBCs removed yielded a ten-year data set with 3,455-recorded incidents.

Getis-Ord Hot Spot Analysis

Overview

In this section the reasons for the selection of the Getis-ord Gi* method are given, and then the eight steps necessary to repeat this analysis are presented.

Analyses were conducted using the Universal Transverse Mercator (UTM) projection, Zone 11N, North American Datum of 1983, meters as specified by NDOT GIS personnel. Area and magnitude calculations were conducted in meters and relayed as equivalent Imperial measurement values. Common conversions reported here include 0.5-miles = 804.672 meters, 1-mile = 1609 meters, and 2-miles = 3218 meters.

Introduction to the Selection of Getis-Ord Gi as the Hot Spot Mapping Tool*

Hot spot analyses for the Nevada *Animal-Vehicle Crashes* (AVC) and the Nevada *Recorded Carcass Locations* (RCLs) datasets were completed using the Esri® ArcGIS 10.5.1 Getis-Ord Gi* statistic tool called *Optimized Hot Spot Analysis* (OHSA) (http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-statistics-toolbox/optimized-hot-spot-analysis.htm). These methods are applicable with versions 10.4 and greater of Esri ArcGIS.

The OHSA spatial statistic was used because it employs a polygon aggregation as a critical part of the analysis method. Past studies have used the OHSA spatial statistic to create hot spot maps of AVC crash and carcass data (Garrah et al. 2015, Kociolek et al. 2016, Shilling and Waetjen 2015). The aggregation polygons allow the user to assess a total number of incidents (crashes) within a given area when each incident, or spatial location, is an independent record. Hot spots are attributed using statistically significant groups binned into 90, 95, and 99 percent confidence intervals.

The OHSA allows the analyst to adapt model parameters to ensure proper values are used given the spatial distribution of the occurrence data. The tool also enables the analyst to select the most appropriate aggregation method, that is, the method by which the points or occurrences may be counted or summarized, for a given area. The ability to summarize data within a given aggregation area is the differentiating feature from the standard *Hot Spot Analysis (Getis-Ord Gi*)* tool available in ArcGIS.

An introduction to Getis-Ord can be found at the following website: (http://resources.esri.com/help/9.3/arcgisengine/java/gp_toolref/spatial_statistics_tools/how_hot_spot_analysis_colon_getis_ord_gi_star_spatial_statistics_works.htm)

Steps in the Getis-Ord Gi Hotspot Analysis*

The steps detailed below can be summarized in the following nine points:

1. Obtain most recent NDOT Roads geo-referenced files, and crash data
2. Collapse multi-lane roads into a single line feature
3. Buffer Roads by 500 feet
4. Determine center line of the road polygons
5. Develop 0.5-mile aggregated polygons for all NDOT roads
6. Apply the Optimized Hot Spot Analysis Tool (OHSA) to the Road and Crash Data
7. Interpret Output Data at Different Confidence Intervals
8. Interpret Output Data at Different Scales
9. Generate Statewide and NDOT Districts Top 20 Maps and Tables

Greater detail on these and additional steps are provided in the guidebook (A Word file titled, 'Guidebook for Creating Priority Hotspot maps based on NDOT crash data July 2018') submitted with the ArcGIS data and available on the NDOT internal website.

APPENDIX F. WILDLIFE CROSSING STRUCTURES AND FENCING PROJECTS IN NEVADA

Table 57. Wildlife Crossing Structures and Fencing in Nevada as of 2017. Green Shaded Rows Designate Structures Constructed Specifically for Wildlife or Horse Movement.

Project Name	Road	MM	Structure Type and Size	Target Species	Status as of Summer of 2017	Year Com-plete	Notes
Northeast NDOT District III							
Pequop Summit	Interstate 80	90.9	Large Steel Arches Overpass	Ungulates	Under Construction	2017	
Pequop Summit	Interstate 80	97.4	Large Steel Arch Overpass	Ungulates	Under Construction	2017	
Pequop Summit	Interstate 80	99	Large Multi-Use Bridge Underpass	Ungulates	Complete	Unknown	Low vehicle use
Pequop Summit	Interstate 80	95	Large Multi-Use Bridge Underpass	Ungulates	Complete	Unknown	Low vehicle use
Pequop Summit	Interstate 80	95	Medium Concrete Box Underpass	Ungulates	Complete	1980's	Un-known if built for wildlife
Pequop Summit	Interstate 80	97	Medium Concrete Box Culvert Underpass	Ungulates	Complete	1980's	Un-known if built for wildlife
Silver Zone	Interstate 80	113.8	Large Concrete Arches Overpass	Ungulates	Completed	2013	
Silver Zone	Interstate 80	113	Large Rail Road Multi-Use Bridge Underpass	Ungulates	Completed	2013	
Silver Zone	Interstate 80	115	Large Rail Road Bridge Multi-Use Underpass	Ungulates	Completed	2013	
10 Mile Summit	US 93	83.4	Large Concrete Arches Overpass	Ungulates	Completed	2010	
10 Mile Summit	US 93	82.1	Large Corrugated Steel Culvert Underpass	Ungulates	Completed	2010	
10 Mile Summit	US 93	84.8	Large Corrugated	Ungulates	Completed	2010	

Project Name	Road	MM	Structure Type and Size	Target Species	Status as of Summer of 2017	Year Com-plete	Notes
			Steel Culvert Underpass				
HD Summit	US 93	93.5	Large Concrete Arches Overpass	Ungulates	Complete	2011	
HD Summit	US 93	92.6	Large Corrugated Steel Culvert Underpass	Ungulates	Complete	2010	
HD Summit	US 93	89.1	Large Concrete Box Underpass	Ungulates	Complete	2016	
West NDOT District II							
Dayton Valley	US 50	16	Large Concrete Box Culvert Underpass	Horses	Completed	2013	
USA Parkway	USA Parkway	15.6	Large Concrete Box Culvert Underpass	Horses	Complete	2017	
USA Parkway	USA Parkway		Large Concrete Box Culvert Underpass	Horses	Complete	2017	
I-580 / Steamboat	I-580		Large Open Span Bridge Underpass	Ungulates	Complete	2012	
I-580 / Steamboat	I-580		Large Open Span Bridge Underpass	Ungulates	Complete	2012	
I-580 / Steamboat	I-580		Large Open Span Bridge Underpass	Ungulates	Complete	2012	
I-580 / Steamboat	I-580		Large Open Span Bridge Underpass	Ungulates	Complete	2012	
Southern NDOT District I							
Hoover Dam	US 93	2	Large Concrete Box Underpass	Ungulates	Completed	early 2000's	
Hoover Dam	US 93	1	Large Open Span Bridge Underpass	Ungulates	Completed	early 2000's	
Hoover Dam	US 93	0.5	Large Open Span Bridge Multi-Use Underpass	Ungulates	Completed	early 2000's	Local road Low vehicle use

Project Name	Road	MM	Structure Type and Size	Target Species	Status as of Summer of 2017	Year Com-plete	Notes
Hoover Dam	US 93	0.5	Large Open Span Bridge Multi-Use Underpass	Ungulates	Completed	early 2000's	SR 172 highway High vehicle use - low probability of wildlife use
Hoover Dam	US 93	0.5	Large Open Span Bridge Multi-Use Underpass	Ungulates	Completed	early 2000's	Hoover Dam Access road - High vehicle use - low probability of wildlife use
Boulder City Bypass	US 93 / I-11	Not yet	Large Concrete Arches Overpass	Ungulates	Final Planning	2018	Concrete or Steel Arches
Boulder City Bypass	US 93 / I-11	Not yet	Large Open Span Bridge Underpass	Ungulates	Final Planning	2018	
Boulder City Bypass	US 93 / I-11	Not yet	Large Open Span Bridge Underpass	Ungulates	Final Planning	2018	
Boulder City Bypass	US 93 / I-11	Not yet	Large Open Span Bridge Underpass	Ungulates	Final Planning	2018	
Boulder City Bypass	US 93 / I-11	Not yet	Large Open Span Bridge Underpass	Ungulates	Final Planning	2018	
Mountain Springs	SR 160		Large Closed Span Bridge Underpass	Ungulates	Final Planning	2019	Spans are enclosed like a culvert 32' high one side, 20' another side

Maps of wildlife crossing structure locations are presented in Figures 64 through 67, below.

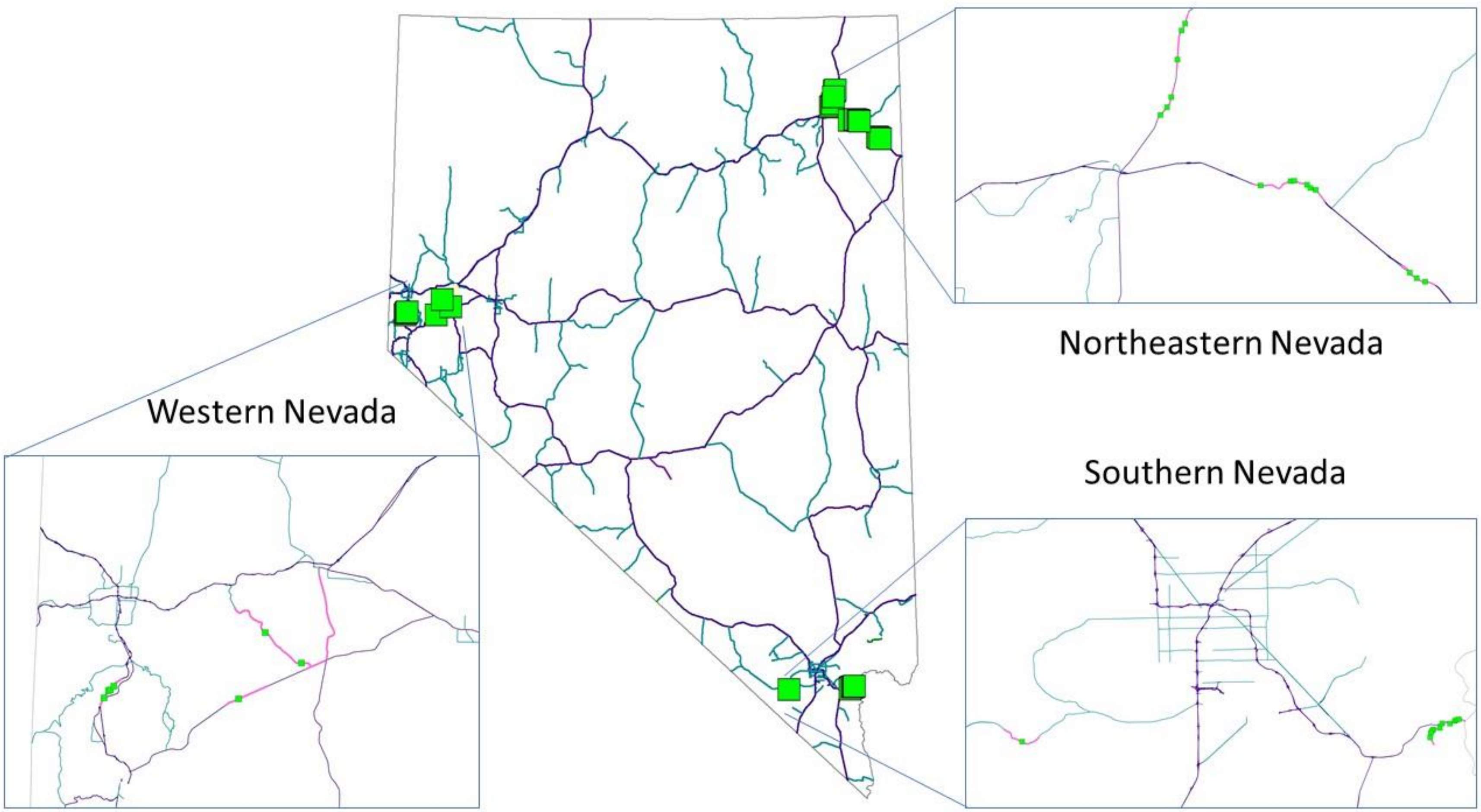

Figure 64. Wildlife Crossing Structures and Wildlife Fencing in Nevada as of 2017.

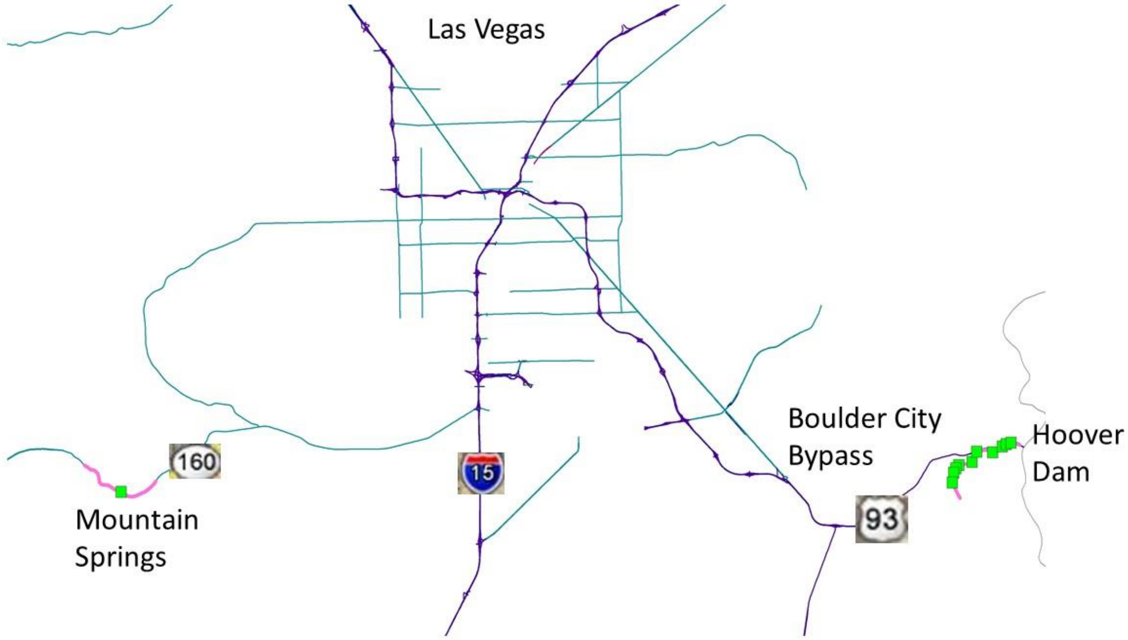

Figure 65. NDOT District I, Southern Nevada Wildlife Crossing Structures and Fencing Projects.

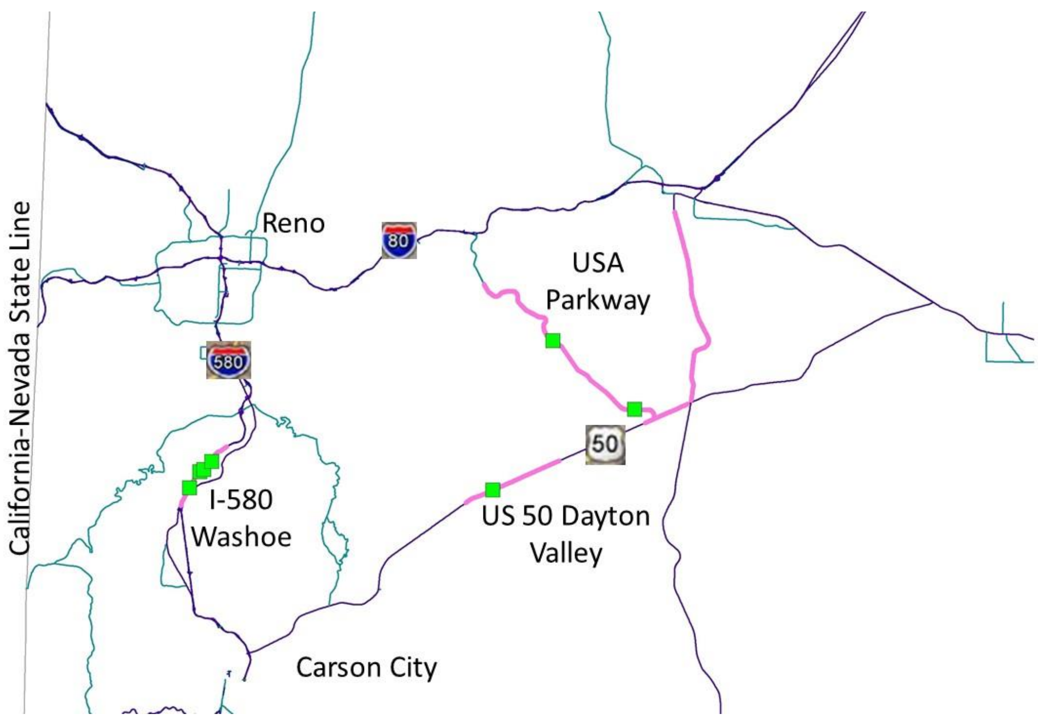

Figure 66. NDOT District II Western Nevada Wildlife and Horse Crossing Structures and Fencing Projects.

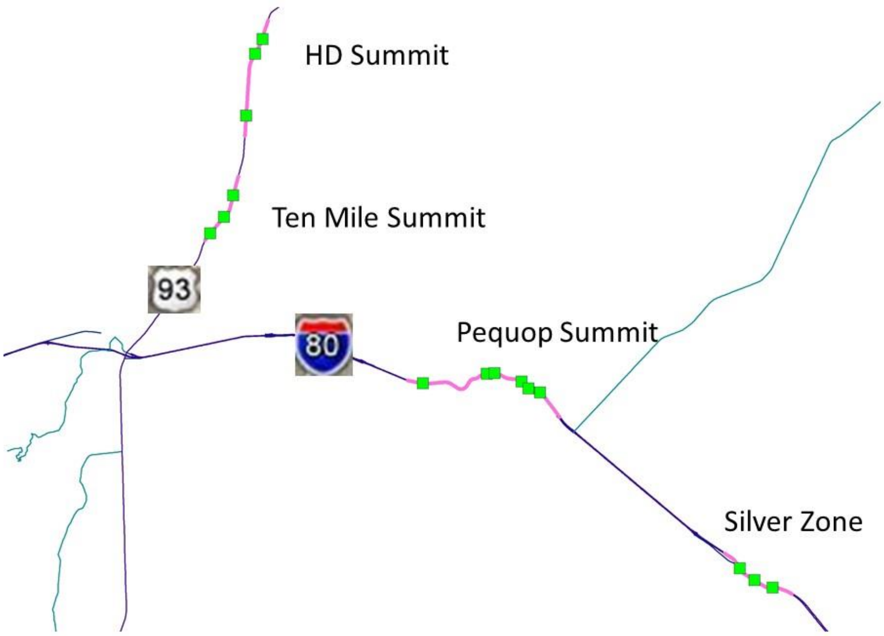

Figure 67. NDOT District III Northeastern Nevada Wildlife Crossing Structures and Fencing Projects.

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