NV-RDT-06-010

NDOT Research Report

Evaluation of Wildlife Warning Systems and other Countermeasures

October 2006

A Report on Research Sponsored by

Nevada Department of Transportation
Carson City, Nevada

and

Federal Highway Administration

Disclaimer

This work was sponsored by the Nevada Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of Nevada at the time of publication. This report does not constitute a standard, specification, or regulation.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. **NV-RDT-06-010**	2. Government Accession No.	3. Recipient=s Catalog No.
4. Title and Subtitle **Evaluation of Wildlife Warning Systems and other Countermeasures**	5. Report Date **October 2006** 6. Performing Organization Code	
7. Author(s) **A. Reed Gibby, Roma Clewell**	8. Performing Organization Report No.	
9. Performing Organization Name and Address **Nevada Department of Transportation** **Research Division** **1263 So. Stewart Street** **Carson City, NV 89712**	10. Work Unit No. 11. Contract or Grant No. **29002000**	
12. Sponsoring Agency Name and Address **Nevada Department of Transportation** **Research Division** **1263 So. Stewart Street** **Carson City, NV 89712**	13. Type or Report and Period Covered 14. Sponsoring Agency Code **NDOT**	
15. Supplementary Notes		

16. Abstract

This report examines Nevada deer-vehicle collisions during 2000-2004. The research evaluates the effectiveness of animal warning systems and other countermeasures initiated to protect the motoring public and deer populations. The project also includes a literature review so promising, low cost countermeasures can be considered for field evaluation and countermeasures of higher cost can be recommended for integration into construction projects. A research technical panel, composed of employees of Nevada Department of Transportation (NDOT) and Nevada Department of Wildlife (NDOW), directed the research study. The Nevada highways with a high propensity for deer-vehicle collisions were US 93 north of Wells, Nevada, and I-80 in the vicinity of Pequop Summit. The literature review revealed only one 'effective' countermeasure, which was the wildlife grade separation. Six countermeasures of 'promise' were also identified: 1) wildlife grade separations with exclusionary fencing and vegetation, 2) deer crossing warning signs activated during migration, 3) deer crossing warning signs activated by presence of deer, 4) at-grade crossings with exclusionary fencing and warning signs, 5) roadside reflectors, and 6) roadway lighting.

The recommended countermeasures for field evaluation were: 1) Construct and evaluate an overpass structure with exclusionary fencing and vegetation at a high collision location on US 93. An economic analysis revealed a Benefit-Cost Ratio of 2.6, 2) Install and evaluate an at-grade deer crosswalk with exclusionary fencing and escape gateways, deer-warning signs with flashers, sensors to detect animals, and painted cattle guards at a high collision location on US 93 and 3) Install and

evaluate high-level luminaries on I-80, Pequop Summit using surplus luminaries.

17. Key Words		18. Distribution Statement	
deer-vehicle collisions, animal warning systems, wildlife grade separation, warning signs, deer fencing, roadside reflectors, lighting, deer detection, economic analysis		**Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161**	
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. Of Pages **32**	22. Price

Acknowledgements

This report describes research that was funded by the Nevada Department of Transportation (NDOT). The conclusions and recommendations presented in this report are those of the authors only, and shall not be construed to be endorsed by NDOT.

The authors wish to thank NDOT Panel Members: Debra Sternes, NDOT District II, Kevin Lee, NDOT District III, James Murphy, NDOT Environmental, Kent Mayer, NDOT Maintenance, Mike Cox, Nevada Department Of Wildlife (NDOW), and Reed Gibby, NDOT Research. In addition, the report was reviewed by Tony Grossman, Habitat Staff Specialist, NDOW and Marcel Huijser, Western Transportation Institute, Montana State University and edited by Roma Clewell, NDOT Research.

ABSTRACT

This report examines Nevada deer-vehicle collisions during 2000-2004. The research evaluates the effectiveness of animal warning systems (countermeasures) initiated to protect the motoring public and deer populations. The project also includes a literature review so other promising, low-cost countermeasures can be considered for field evaluation and countermeasures of higher cost can be recommended for integration into construction projects.

A research technical panel, composed of employees of Nevada Department of Transportation (NDOT) and Nevada Department of Wildlife (NDOW), directed the research study that consisted of several tasks. The first step of this research effort was an extensive national literature review with some information obtained from international sources. The literature search included a summary of literature findings. Analysis of collision data was the next step to determine those areas in the state where there have been concentrations of deer-vehicle collisions. The highways with a high propensity for deer-vehicle collisions were US 93 north of Wells, Nevada, and I-80 in the vicinity of Pequop Summit. The third task was to document the existing deer countermeasures currently installed along these highways and discuss their effectiveness. The selection and analysis of possible countermeasures that seemed appropriate for the circumstances on US 93 and I-80 was the next task. The fifth task was the assessment of the selected countermeasures followed by formal recommendations. The last research task documented the major implementation issues.

The literature review revealed only one ‘effective’ countermeasure, which was the wildlife grade separation. Six countermeasures of ‘promise’ were also identified: 1) wildlife grade separations with exclusionary fencing and vegetation, 2) deer crossing warning signs activated during migration, 3) deer crossing warning signs activated by presence of deer, 4) at-grade crossings with exclusionary fencing and warning signs, 5) roadside reflectors, and 6) roadway lighting.

Recommendations were provided that relate to the goal of identifying specific countermeasures to reduce the number of deer killed on Nevada highways:

1) Construct and evaluate an **overpass structure with exclusionary fencing and vegetation** at a high collision location on US 93. An economic analysis revealed a Benefit-Cost Ratio of 2.6.

2) Install and evaluate an **at-grade deer crosswalk with exclusionary fencing and escape gateways, deer-warning signs with flashers, sensors to detect animals, and painted cattle guards** at a high collision location on US 93.

3) Install and evaluate **high-level luminaries** near MP 96, Pequop Summit using surplus luminaries.

There are also policy recommendations resulting primarily from the literature search of this research project that would likely affect NDOT at the program level.

1) As a part of the environmental process for major projects, formal wildlife connectivity analysis should be conducted.

2) Wildlife migration data will need to be developed for corridor studies.

3) Bridge, culvert, and tunnel construction, and reconstruction projects should be designed to accommodate wildlife migration patterns.

4) For improvements initiated by the Districts, contact with NDOW should occur in the event the scope of the District improvements can be altered to help reduce vehicle collisions with wildlife.

5) Initiate a comprehensive, statewide, big game-vehicle collision reporting system with all appropriate public safety, transportation, and natural resource agencies involved with data collection.

TABLE OF CONTENTS

TABLES

EVALUATION OF WILDLIFE WARNING SYSTEMS

1.0 INTRODUCTION

1.1 BACKGROUND

Historically deer have played an important role in the United States. Before 1500 AD an estimate suggested that the North American white-tailed deer population was approximately 30 million, which dropped below 2 million by 1900, mostly due to hunting by humans. Presently, the total United States deer population is approaching 30 million (Hedlund, 2003). This increase in deer population occurred primarily because of a reduction in the population of natural predators and deer hunting restrictions.

According to the best estimates currently available within the United States, there were 1.5 million deer-vehicle collisions during 2002 with $1.1 billion in losses due to vehicle damage. Additionally in 2002, an estimated 150 humans and 1.5 million deer were killed. While several states have reported reductions in deer-vehicle collisions, the current, overall national trend in deer-vehicle collisions, based on reported collisions, showed an increase of approximately 24% during the 1990s (Hedlund, 2003). The increase in collisions is primarily due to growth in deer population and vehicle miles-of-travel on roadways near deer feeding sites or areas that cross deer migration paths. Secondarily, there has probably been some improvement in reporting deer-vehicle collisions that will reduce the under-reporting of these collisions.

In Nevada, 2002 statewide crash records reported 698 collisions between larger animals (antelope, bear, burros, cows, elk, deer and horses) and motor vehicles. The involvement of deer and cows was 60% and 25%, respectively. Horses were involved in 6% of the collisions. All other animals (antelope, bear, burros and elk) combined were involved in the balance of 9% (Nevada Crash Data, 2002). This data also suggests that the collisions with cows and horses appear to be more severe than with deer. Since fencing easily controls cows and the Nevada Department of Agriculture relocates wild horses that stray near highways, this research project focused on reducing deer-vehicle collisions, although some mechanisms that are effective with deer may also be effective with some of the other larger wildlife.

1.2 NATURE OF THE PROBLEM

Many rural highways have been constructed through deer migratory routes between winter and summer ranges and also deer habitats. Additionally, the expansion of human development into deer habitats has increased the deer-human interaction, which is reflected in an increase of deer crossing highways, streets, and roads. The increase in deer crossings typically equates to an increase in deer-vehicle collisions. Furthermore, the intercity travel has increased on rural roads, especially the higher speed interstates; the number, as well as the severity of deer-vehicle collisions, has increased and will continue increasing unless effective countermeasures are installed. In states like Nevada, where the mule deer (Odocoileus hemionus) migrate between winter and summer feeding ranges, the migration patterns intersect major highways.

Another major problem is a lack of reliable crash data due to unreported deer-vehicle collisions. Studies in other states have indicted more than 50% of the deer-vehicle collisions nationwide are not reported (Deercrash, 2006). However, it is very likely that deer-vehicle collisions vary from state to state and probably within individual states. It is also possible that within or near urban areas deer-vehicle collisions are more likely to get reported than deer-vehicle collisions that occur in remote areas of a state. Based on a small, but recent sample, Department of Wildlife (NDOW) data reported that 29% of deer-vehicle collisions are reported to authorities on a rural section of I-80. Without reliable collision data, the magnitude and location of deer crossing problems may be difficult to properly determine. Thus, the evaluation of any countermeasures will be difficult.

1.3 RESEARCH OBJECTIVE

A major objective of this project is to evaluate the effectiveness of animal warning systems (more generally characterized as countermeasures) that should help protect mule deer, as well as, the motoring public. Initially, the research project was to focus on proprietary roadside reflectors, a low cost countermeasure. When the Nevada Department of Transportation (NDOT) Research Management Committee approved the project, instructions were provided to expand the objective to consider other countermeasures in addition to the roadside reflectors. Consequently, a literature review was added so other promising, low-cost countermeasures could be considered for field evaluation and promising countermeasures of higher cost could be recommended for integration into construction projects.

1.4 METHODOLOGY

A research technical panel, composed of employees of NDOT and NDOW, directed this research study that consisted of several tasks. The first step of this research effort was an extensive national literature review with some information obtained from international sources. The literature search included a summary of major literature findings. Analysis of collision data was the next step to determine those areas in the state where there have been concentrations of deer-vehicle collisions. The highways with a high propensity for deer-vehicle collisions were US 93, north of Wells, Nevada, and I-80 in the vicinity of Pequop Summit. The third task was to document the existing deer countermeasures currently installed and discuss their effectiveness. The selection and analysis of possible countermeasures that seemed appropriate for the circumstances on US 93 and I-80 was the next task. The fifth task was the assessment of the selected countermeasures followed by formal recommendations. The last research task documented the major implementation issues.

2.0 LITERATURE REVIEW

2.1 OVERVIEW

The literature review identified potential countermeasures by various authors (Hedlund, 2003; Knapp, 2005; Watson, 2000; Danielson, 1998) that have been grouped into several categories. They are: motorist warning systems, deer warning systems, deer control systems, management techniques, and non-intervention systems. Since one important aspect was an economic analysis, the economic value of deer and the evaluation of the countermeasures were also searched as part of the literature review.

2.2 MOTORIST WARNING SYSTEMS

The basic motorist warning systems include: deer crossing warning signing, on-board detection, and warning systems.

2.21 Deer Crossing Warning Signing

There are three general types of warning systems: the standard, activated during migration, and activated by presence of deer.

2.211 Standard Warning Sign

The passive standard deer crossing signs (W-3) have been used extensively. Since the standard practice is to place them permanently along the roadway, the message to the driver suggests a year-round warning. Because the probability of a collision is very small, such warnings are usually not heeded. Apparently, the signs are not effective because none of the evaluation studies found that they increased driver awareness, reduced vehicle speed, or reduced deer-vehicle collisions. The main reason for using these ineffective warning signs is likely to avoid potential legal problems. The state Department of Transportations (DOTs) argue that the signs were installed based on the Manual on Uniform Traffic Control Devices (MUTCD). Variations of this countermeasure included the addition of flashing lights and/or flags and animated deer figures. The only study found to deal with flashing lights and animated deer figures concluded that vehicle speeds were reduced slightly, but were not effective in reducing deer-vehicle collisions.

2.212 Activated During Migration

Two studies were completed for warning signs ‘in-place’ during migration. These warning systems usually include signs with flashers that were activated during the migration season. A variation to the activation is to uncover passive warning signs with flashers during migration. One study reported a reduction in speed and deer-vehicle collisions while the other study did not. Some differences included sign design and deer species. Apparently, better designed field-testing and evaluation is needed. A tri-state (Utah, Idaho, and Nevada) research study evaluating deer migration warning signs with flashing lights will be discussed in more detail later. In general, this countermeasure was effective in reducing deer-vehicle collisions.

2.213 Activated by Presence of Deer

There are more advanced systems classified as Intelligent Transportation Systems (ITS), wherein sensors detect animals near the roadway at designated deer crossing sites activating deer crossing signs to warn motorists of probable wildlife on or near the highway. A recent, extensive study (Huijser, 2006) on animal detection systems reported that more than 30 installations have occurred in Europe and North America. There are different types of Intelligent Transportation Systems that have been installed or are under serious consideration. However, the study reported that only two systems, one in Wyoming and the other in Pennsylvania, have been installed and are being thoroughly evaluated through a pool funded research study sponsored by 15 state DOTs and the Federal Highway Administration (FHWA). The experimental detection systems were developed in partnerships with two vendors. One system was successful in detecting larger animals while the other system was not. Data collection currently in progress suggests that by lowering highway traffic speeds, collision risks are lowered, especially for inclement weather. Data also shows that detection systems can reduce collisions, but the sample size is too small for validation in this study. The systems are experimental and the numerous problems have been documented. Fortunately, more field trials of deer activated crossing systems are planned in Arizona, California, Colorado, and New Mexico.

2.22 On-Board Detection

Recent developments in the area of Intelligent Transportation Systems would appear to have application with deer-vehicle safety. Demonstrations have been conducted for 'on-board' radar (or infrared cameras) that enable motorist to be warned of dangerous objects critically nearby. Clearly, such a system has merit but needs additional, innovative work to detect and identify deer and other large animals. Few vehicles are equipped with "on-board" radar since this is a new technology. Consequently, it will be a number of years before such a system could make a substantial impact. However, if the technology can be developed for providing effective warning of large animals, this may prove to be one of the less expensive countermeasures for state DOTs because the cost of on-board devices will most likely be born by the drivers.

2.23 Deer Warning Systems

There are two types of deer warning systems, namely, deer whistles and roadside reflectors.

2.231 Deer Whistles

The deer whistle countermeasure is simply a whistle attached to the outside of a vehicle, which is activated by wind when the vehicle approaches 30 mph and produces an ultrasonic noise approximately 16,000 to 20,000 Hz in sound frequency. At this range, the noise from the whistles is not detectable to humans. The whistle technique has been tried for over 20 years even though it is generally recognized as one of the least effective warning systems. Most of the testing and evaluation suffer from poor experimental design and/or documentation. As with other warning systems, this one needs better designed field-testing and evaluation. One of the best studies conducted, had vehicles with whistles drive by deer herds; there was no observed change in deer behavior. Recent testing of the hearing abilities of deer revealed that the deer hearing frequency range is 2000 to 6000 Hz, which might explain why the deer did not react to the whistles. Additionally, there is a concern that the traffic noise will interfere with the whistle noise.

In Canada, a field test is under way where whistles are placed along the roadway and are activated when a vehicle is detected nearby. In general, the literature does not give this warning system a favorable report.

2.232 Roadside Reflectors

The roadside reflectors are popular with many public agencies for two reasons. The reflector systems are relatively inexpensive and the marketing is good. The roadside reflector literature for this countermeasure can be grouped into two broad categories. The first category monitors differences in deer-vehicle collisions applying a cover/uncover method, or conducting before-and-after or control-treatment study approaches to evaluate their impact. In the second category, researchers have either observed deer movements as they evaluated the impact of roadside reflectors on deer-vehicle collisions or specifically considered deer behavior toward reflected light.

In general, 5 of 10 studies concluded that roadside reflectors do not appear to change deer-vehicle collisions; and 2 of the 10 concluded that they did. The other 3 studies appeared to reach inconclusive or mixed results. Most of the studies that evaluated deer behavior (many dealing with captive deer) were also inconclusive or concluded that the deer either did not appear to react to the light from the reflectors and/or quickly became habituated to the light patterns. Unfortunately, the experimental designs and details of all the studies varied, and comparisons of their results are imprecise. The significant amount of speculative and anecdotal information that exists about roadside reflector, deer-vehicle collisions-reduction effectiveness was not included in this summary. However, Appendix C contains considerable discussion on the effectiveness of these devices.

At this point in time it is difficult to conclude whether the roadside reflector/mirror devices are effective due to the conflicting results of the studies. A well-designed, widespread, long-term, statistically valid study of comparable and well-defined roadside reflector treatment and control roadway segments should be conducted.

2.3 DEER CONTROL SYSTEMS

There are six basic types of systems that have been used to control the movement of deer on or near roadways. They are deer-flagging models, intercept feeding, repellents, exclusionary fencing, wildlife grade separations, and at-grade crossings.

2.31 Deer-Flagging Models

Since white-tailed deer raise their tails when troubled, a field test was conducted in which full-scale models of deer with tails raised were placed near a roadway. These deer models did not impact movement of the deer, who probably concluded the models were a fake. Apparently, the deer models did not sufficiently represent reality or perhaps the deer become habituated quickly.

2.32 Intercept Feeding

Since many deer cross roadways as they migrate to find food, feeding stations were used in several test areas. The feeding stations were placed 1200 feet from the roadways. Some areas, but not all, did lower deer-vehicle collisions; however, there were long-term concerns revealed. The deer may become dependent on the feeding stations and other deer may be attracted to the stations. This countermeasure appears to have some benefits in the short term while better long-term measures are developed.

According to NDOW field biologists, the deer cross highways in northeastern Nevada to migrate between summer and winter ranges for a better climate and not solely for food. Consequently, this countermeasure is not applicable to Nevada conditions.

2.33 Repellents

There are generally two types of chemical and biological repellents, specifically, those with unpleasant taste and unpleasant smell. Repellents have been studied to evaluate deer feeding habit impacts, which produced two major findings. Some repellents cause a temporary reduction, but not a prohibition, in feeding. The deer habituated to the repellents. The other finding was that no repellent deterred a sufficiently hungry deer from feeding. This countermeasure may have some benefit, but only in the short term. Another concern is that predators may “learn” that the repellents suggest deer are nearby.

2.34 Exclusionary Fencing

In general, exclusionary fencing is installed to channel or direct the deer to a location where it is better for the deer to cross a highway. There are several important features that need to be carefully incorporated into the fencing design and layout. Such fencing should be chain link, at least eight feet tall, and include a mechanism for the deer to escape the fencing before being hit by a vehicle. These mechanisms are one-way gates, earthen escape ramps, or grade separations. Additionally, fencing should extend far enough along the roadway to divert most, if not all, deer to a safer crossing location. This control system seems to be the most effective countermeasure in reducing deer-vehicle collisions when used with overpass, bridge, or large culvert structures. Because of the likelihood of erosion, falling trees, human activity, regular patrols are needed to keep the fencing in good working order.

2.35 Wildlife Grade Separations

The most effective countermeasure is also the most expensive. Grade separated structures allow deer and vehicles to cross paths at different elevations thereby preventing deer-vehicle collisions. The more economical structures are under-crossing bridges and large culverts that can also be used by deer to cross under the highways. Some of the literature indicated that the vertical clearance should be 10 feet or more and at least 20 feet wide. Other literature uses an ‘Openness Factor’ (OF) for under-crossings, which are shown below (Watson, 2000). A value of 2.0 or more is recommended when using the following equation:

$$OF = (H)\,(W) / L$$

Where H – height of opening
W – width of opening
L – length of opening

Exclusionary fencing is needed to direct the deer to crossings. In the case of overpasses, the structures need to be wider, perhaps as much as 1500 feet as is common in Europe. An overpass in Canada, which was very effective, provided a crossing width for animals of 165 feet. Incidentally, the deer are more likely to use these crossings when the structures resemble natural habitats. This includes an earth floor, native vegetation, ‘woody’ cover at entrances, and a clearly visible exit. A very successful application in Wyoming consisted of six underpasses in a segment eight miles in length in which the movement of the mule deer was not altered and practically all deer-vehicle collisions were eliminated. Grade separations are probably more useful where the deer have definite migratory routes.

2.36 At-grade Crossings

Because of the expense of grade-separated structures, a set of at-grade crossings (deer crosswalks) have been installed and evaluated. The deer crosswalks were placed on a 17-mile section of highway in Utah. The highway consisted of 13 miles of two-lanes and 4 miles of four-lanes divided with nine crossings created. Fencing directed the deer to the edge of the shoulder; a dirt pathway bordered by cobblestones was placed over the shoulders and the median. This structure channeled the deer to crossings where painted cattle guards directed the deer across the travel lanes. The standard, passive deer warning signs were also placed at the crosswalks. As with other countermeasure studies, the number of collisions were not conclusive this time because a control section was not available; however, the deer-vehicle collisions were reduced nearly 40%. More research with this formal experimental design is needed before the effectiveness of deer crosswalks can be determined.

2.4 MANAGEMENT TECHNIQUES

There are three management techniques that have been used to reduce the hazards to deer crossing highways. They are: herd reduction, roadside vegetation, and deicing salt alternatives

2.41 Herd Reduction

Without a substantial population of predators, deer populations can be become excessive. There have been deer population studies done regarding deer hunting, which implied that a reduction in deer population should, subsequently, lead to reduced deer-vehicle collisions. Sometimes in states with large deer population, i.e. Michigan with nearly 1.9 million in 2003, the number of deer-vehicle collisions is used as one factor in herd management (Deercrash, 2006).

In Nevada, mule deer population statistics for 2005 listed a relatively small count of approximately 107,000 deer statewide (Cox, 2005) compared with other states. Consequently, herd reduction is not a viable option politically.

2.42 Roadside Vegetation

The presence of roadside vegetation has not been sufficiently studied. The concern is that roadside vegetation will attract wildlife and increase the probability of collisions with vehicles. There is one study that probed the presence of vegetation and moose-vehicle crashes, but the reduction in crashes was not large enough to be conclusive. Another aspect of roadside vegetation is to have a clear zone where taller vegetation has been removed so that the deer are easier to see. One study found a positive relationship between deer-vehicle collisions and proximity to the forest cover.

The roadside vegetation is a non-issue because, in most areas of Nevada, there is not sufficient roadside vegetation to attract deer to the roadside for the purpose of feeding. Additionally, there is not enough roadside vegetation to hide deer during the daylight hours.

2.43 Deicing Salt Alternatives

There have been authors that imply deer might be attracted to salt used to deice roadways. Suggestions have been made to use other products to deice roadway sides. Based on field observation, this can be a problem with moose, which do not appear to be intimated by vehicles (Rea, 2005); however, no studies or field observations regarding deer were found.

2.5 NON-INTERVENTION SYSTEMS

There are two countermeasures that do not intervene in any way with the migration of deer. These measures are public information programs and roadway lighting.

2.51 Public Information Programs

There have been attempts to educate, in general terms, the public regarding various hazards associated with deer-vehicle collisions; however, none of the general programs were evaluated. In traffic safety, some programs were probably helpful in providing some temporary awareness of safety issues, but were not effective. In 2003, a pedestrian safety program in California provided pedestrian safety 'PR spots' on TV news, radio, and movie theaters. Six months later a random public survey was conducted in the four largest urban areas to determine how many people remembered the spot. About 20% of the public saw or heard the spot and 62% of that population reported that the spot affected their behavior as either a motorists or a pedestrian. However, the pedestrian-vehicle collisions were not compiled before or after the spots aired. Some education programs have been directed towards enlightening motorists about deer-vehicle collisions hazards, but none of the programs were evaluated for effectiveness.

Public information programs in rural areas tend to be less effective because the majority of motorists do not routinely use a particular highway. In urban areas, where motorists regularly drive the same roadways, public education programs can be more effective.

2.52 Roadway Lighting

A major concern with deer-vehicle collisions is that motorists are surprised by the presence of deer on the roadway and do not have sufficient time to react safely. This is especially true on rural, mountain roadways with numerous horizontal and vertical curves. Surprised motorists tend to engage in panic stops or swerve to avoid colliding with deer. Either action may cause more personal and vehicular damage than colliding with the deer. Since the majority of deer-vehicle collisions occur at nighttime, it is reasonable to assume that roadway lighting might reduce these collisions. The use of high-level illumination provides substantial light on the roadway. With such lighting, motorist will more likely see deer that are crossing the highway in time to slow down and/or maneuver to avoid colliding with the deer. Roadway lighting of this nature in rural areas is normally reserved for freeway interchanges; however, if the lighting can reduce a large number of deer-vehicle collisions, the cost of the illumination will likely be justified.

This countermeasure is yet to be sufficiently studied, since the only research report described a test segment in Colorado on a 0.75-mile segment for two weeks – one week the illumination was on and the second week it was off. With the lighting on, there was a decline of about 18% in the rate of deer-vehicle collisions. This was only a small data sample; consequently, a much larger scale research effort is needed. There is the possibility the illumination will cause the deer to shy away and seek a darker environment to cross the highway. Any new research studies should address this issue.

2.6 ECONOMIC IMPACT OF DEER-VEHICLE COLLISION

Attempts have been made to determine the positive and negative monetary value of deer. In general, the recreational value of deer in the mid 1990s on a national scale was estimated to be more than $14 billion while the cost of the deer was approximately $2 million. This analysis by Conover (Conover 1995) did not attempt to place a value on human life or injury as there were an estimated 211 fatalities and 29,000 human injuries caused by deer-vehicle collisions. In his literature review, Schafer (Schafer, 1985) cites sources that assigned an economic value to a Deer equal to $350 in 1976 by a Colorado court. In Nevada, a report (Kay 1988) stated that the monetary value of a deer was $703.64 in 1988. An Iowa court placed the value of poached antlered white-tail deer at $3,000 in 1998 (Danielson, 1998). Based on a Canadian Breeder's Classic sales for farmed deer, the bred doe sold for an average of $2,833 in Canadian money (Deertracking, 2002). A researcher in Utah reported 2003 cost data for the average vehicle damage for deer-vehicle collisions at $1,574 and the value of a deer at $2,667 (Kasser 2004). In 2004 the Texas Parks and Wildlife Commission established the value of a mule deer at $1,801 based on the restoration cost of deer over a five-year period in Texas (Texas Commission, 2004).

2.7 MAJOR LITERATURE FINDINGS

One of the most common findings suggests that work accomplished with deer-vehicle collisions countermeasures has not been adequately documented and analyzed. The design of many studies probably did not anticipate the complex nature of accurately quantifying changes in the deer-vehicle collisions. To evaluate the possible reduction in deer-vehicle collisions in Nevada, study designs need to deal with such matters as small sample sizes, rapid growth in highway travel, changes in migration patterns due to microclimate variations, variations in deer population and population density, changes in human development, changes in the level of reported deer-vehicle collisions, changes in highway geometry, and changes with the treatment of roadside vegetation.

The following is a listing of the countermeasures that appeared effective or showed promise of being effective:

Effective Countermeasures:

1. Wildlife Grade Separations with Exclusionary Fencing

Countermeasures with Promise:

1. At-grade Deer Crossing Warning Signs Activated during Migration with Exclusionary Fencing
2. At-grade Deer Crossing Warning Signs Activated by Presence of Deer with Exclusionary Fencing
3. Roadside Reflector
4. Roadway Lighting

3.0 ANALYSIS OF COLLISION DATA

3.1 OVERVIEW

The overall analysis of deer-vehicle collision data provided helpful information in several ways. First, a statewide plot of deer-vehicle collisions for a recent 5-year period was prepared. Major concentrations of deer-vehicle collisions were identified on US 93, north of Wells, and I-80 near the Pequop Summit. Consequently, this chapter discusses the collision data on US 93, between Wells and Jackpot, and I-80 in the vicinity of Pequop Summit. The collision data for US 93 included the reported deer kills, as well as, collisions while the I-80 data only included the collisions. The number of collisions is only the reported collisions, which understates the magnitude of the problem since many collisions remain unreported. During the fall of 2005, along I-80 in the vicinity of Pequop Summit, NDOW collected field data that indicated only 29% (8 of 28) of the deer kills were reported. While the sample was not large, this reporting rate is similar to a source from Utah, an adjacent state, indicating that only 15% to 20% of deer-vehicle collisions were reported (Sullivan, 2003).

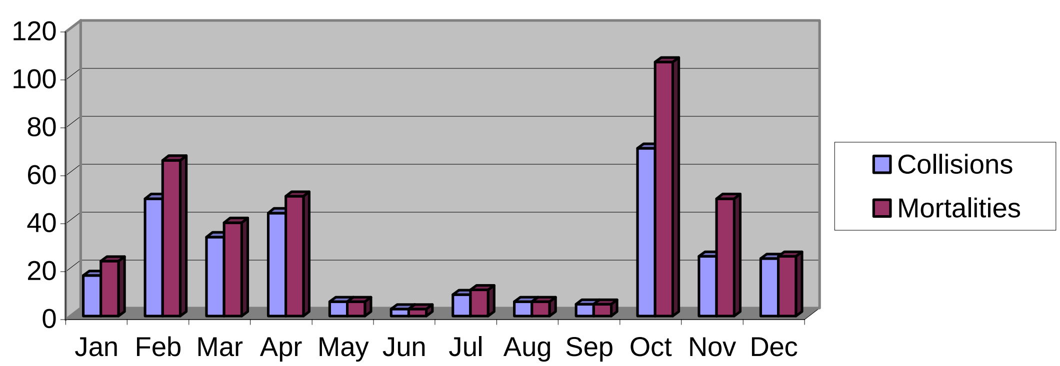
3.2 US 93 COLLISION DATA

The 2000 through 2004 collision data on US 93 began at milepost 76, just north of Wells and ended at milepost 140, near the Nevada-Idaho border. Table 3-1 shows that 388 deer were reported killed in 290 deer-vehicle collisions over a 65-mile section of US 93, which averages almost 80 reported deer killed per year. Using the 29% statistic for unreported deer collisions, this annual figure is really closer to 300. The collision pattern in Table 3-1 clearly indicates that the months of October through April are when the migration of the deer herds occurs, with October and November, and February through April being the most severe months. Figure 3-1 illustrates this pattern.

Table 3-1. Deer Collisions by Month on US 93 North of Wells, NV for 2000 - 2004.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Collisions	17	49	33	43	6	3	9	6	5	70	25	24	290
Mortalities	23	65	39	50	6	3	11	6	5	106	49	25	388

Figure 3-1. Deer Collisions by Month on U.S. 93 North of Wells, NV for 2000 - 2004.



By examining the distribution of the collisions by mile segment, the locations that more likely need warning devices for motorists can be identified. Table 3-2 contains those mile segments with four or more collisions. Some segments have experienced more than 40 reported deer kills. There are 12 one-mile segments with 10 or more deer mortalities, which are combined into five sections as follows: mileposts 83.0 to 85.0 (2.0 miles), 91.0 to 96.0 (5.0 miles), 121.0 to 123.0 (2.0 miles), 125.0 to 127.0 (2.0 miles), and 139.0 to 140.0 (1.0 mile). The use of deer mortalities is a better indicator of the severity of the deer-vehicle collisions.

Table 3-2. Deer Collisions by Mile Segments on US 93 North of Wells, NV for 2000 – 2004.

Collisions	7	13	26	6	5	8	16	8	10	15	5	5	7	30	7	8	37	7	5	8	12
Mortalities	8	19	41	7	5	10	27	14	13	26	9	5	12	40	9	8	47	10	5	8	14
Milepost	82	83	84	85	89	91	92	93	94	95	114	120	121	122	123	124	125	126	131	138	139

Note: Mile segments with more than 4 collisions.

Table 3-3 summarizes the deer-vehicle collision rates on US 93 north of Wells and compares them to the 2002 statewide averages, which is the most recent compiled data available. Again, this is reported data; therefore, the actual number of collisions is approximately 3.5 times greater. The injury and fatal deer-vehicle collision rate was based on the 1998 – 2002 statewide data, which is the most recent 5 years of compiled data available.

The Annual Average Data Traffic (AADT) was obtained from Automatic Traffic Recorder # 0721109, located near milepost 124, for all sections except for the last one, mileposts 139 – 140. For this last section, Elko Portable Count Station #0162, located near milepost 140, was used. For three sections, the deer-vehicle collision rates are high when compared to the statewide average for all vehicular crashes. However, when compared with the Upper Midwestern States (Wisconsin, Minnesota, Michigan, Illinois and Iowa) Nevada has a much higher rate of deer-vehicle collisions. Typically, deer-vehicle collisions are not as severe as crashes in general. Approximately, 4.1% of deer-vehicle collisions injure humans and 0.1% kills humans compared with 33% and 0.5%, respectively of all crashes on the state highways.

Table 3-3. Deer-Vehicle Collision Rates by Sections on US 93 North of Wells, NV for 2000 – 2004.

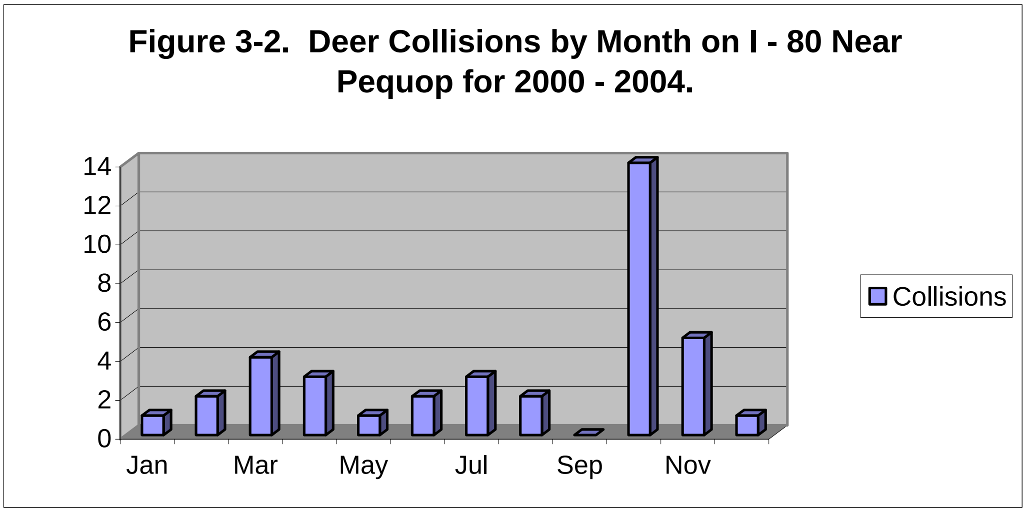
Section	Number of Collisions	Collision Rate (per MVM)
Milepost 83.0 – 85.0	39	5.1
Milepost 91.0 – 96.0	49	2.5
Milepost 121.0 – 123.0	37	4.8
Milepost 124.0 – 127.0	52	4.5
Milepost 139.0 – 140.0	12	1.7
Statewide - 2002		3.24
Upper Midwest - 2002		0.35

3.3 I-80 COLLISION DATA

The number of deer-vehicle collisions on I-80 from milepost 85.0 to 105.0, in the vicinity of Pequop, is shown on Table 3-4. Clearly the number of collisions, 38 in this 20-mile section, is much lower on I-80 than the 388 collisions on the 65-mile section of US 93. It is also clear that the major migration of deer occurs during the month of October. The number of collisions for the other months is so small that none of them vary significantly from their mean, assuming a Poisson distribution. (*Note: The collision data file for I-80 did not include the number of deer killed.)*

Table 3-4. Deer Collisions by Months on I-80 Near Pequop for 2000 - 2004

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Collisions	1	2	4	3	1	2	3	2	0	14	5	1	38



By examining the distribution of the collision by mile segment, the locations that more likely need warning devices for motorists can be identified. Table 3-5 contains those mile segments with 5 (average of one per year) or more deer-vehicle collisions. There are 4 continuous one-mile segments with 4 or more deer-vehicle collision, which forms one four-mile section between mileposts 94.0 and 98.0. The total is 26 collisions. Using the same ratio of collisions to deer killed on US 93, the expected deer killed on I-80 would be about 35, which is a substantial number. With the collision-reporting rate discovered by NDOW, the 26 total collisions in Table 3-5 were probably closer to 91 collisions.

Table 3-5. Deer Collisions by Mile Segments on I-80 near Pequop for 2000 - 2004.

Collisions	5	9	7	5
Milepost	94	95	96	97

Note: Mile segments with more than 4 collisions.

Using the AADT from Elko Portable Count Station #0171, the deer-vehicle collision rate for this segment of I-80 was calculated to be 0.7 collisions per million vehicle miles of travel. While this is much lower than the statewide average of 3.24 collisions per million vehicle miles of travel, it is still approximately two times the rate for the Upper Midwestern States.

3.4 SUMMARY

There are several locations on US 93 where the deer-vehicle collision rate is much higher than the statewide average, which suggests that countermeasures should be considered for implementation. For I-80 the collision data does not indicate the same high level of hazards; however, drivers on interstate freeways are less likely to expect wild animals on the highway than drivers using roadways such as US 93. Additionally, the higher speeds on interstate freeways tend to create more severe collisions.

4.0 CURRENT DEER WARNING SYSTEMS IN NEVADA

The general approach when dealing with wildlife-vehicle collisions is to use the signing based on the MUTCD. Typically, warning signs that are visible year round and that warn motorist of rare events are commonly known to be ineffective; consequently, in the fall of 2001 NDOT installed several warning signs with flashers on US 93, north of Wells, and I-80, near Pequop Summit, in hopes that the deer-vehicle collisions would be reduced. Since the sign installation records were not complete, the NDOT photo log and field trip documented the type and location of the warning signs. September 2001 was the most recent time when the deer warning signs were changed. The warning signs for I-80 and US 93 are shown in Table 4-1 and 4-2 respectively.

Table 4-1. Deer Warning Sign on I-80 Near Pequop.

Eastbound	Milepost	Elko Milepost	
DCS10M1F	369.0	91.1	Bothsides
FDC6M2F	371.7	93.8	Rightside
DCS1F	374.8	96.9	Bothsides
Westbound			
DCS10M1F	377.7	99.1	Bothsides
FDC6M2F	373.1	95.3	Rightside
DCS1F	372.7	94.8	Bothsides

Notes:

DMAxMyF	*Deer Migration Area x miles y flashers*
DCSxMyF	*Deer Crossing Symbol Sign x miles y flashers*
DCS	*Deer Crossing Symbol Sign*
FDCxMyF	*Frequent Deer Crossings x miles y flashers*

The US 93 signing was installed as part of a joint research project with Idaho and Utah (Sullivan, 2004). The study looked at collision data for time intervals when the deer migration was believed to be in progress for two or more years before the installation and one or more years after the installation. For this joint study the migration warning signs with flashers were activated when wildlife biologists determined that a migration was in progress. Overall, the report concluded that the number of collisions for all segments in all states were less when the flashing lights were activated. This analysis compared the two treated segments against two control segments in Nevada, respectively, for a period of two years (2000 - 2001) before and one year after (2002). The first treatment segment, MP 83-85, was coupled with the control segment at MP 92-95 while the second treatment segment, MP 121-123, was coupled with the control segment at MP 124-126. The time interval for the first treatment and control segments was October 1st to November 4th and March 15th to May 8th. The time interval for the second segments was December 7th to February 5th and March 15th to May 8th. The two-year 'before' collision data for the first treatment segment was 34 deer killed while at the control segment 46 deer died. The collisions 'after' period numbered 15 and 10 deer killed, respectively.

The two-year 'before' collision data for the second treatment segment was 14 deer killed while at the control segment 5 deer died. The collisions 'after' period numbered 6 and 12 deer killed, respectively.

Table 4-2. Deer Warning Sign on US 93 is Compounded

Northbound	Milepost	Southbound
DMA3M2F	81.9	
DCS2M1F	83.0	DCS1M1F
DCS1M	84.0	DCS2M
	85.0	DMA3M
DCS	90.5	
	91.0	DCS
	93.3	DCS
DCS	93.7	
	95.3	DCS
DCS9M	118.0	
DCM2M2F	121.0	
	121.9	DCS1M1F
	123.0	DMA2M1F
DCS	125.9	DCS
	126.8	DCS
	127.0	DCS9M

Notes:

DMAxMyF *Deer Migration Area x miles y flashers*
DCSxMyF *Deer Crossing Symbol Sign x miles y flashers*
DCS *Deer Crossing Symbol Sign*
FDCxMyF *Frequent Deer Crossings x miles y flashers*

The first Nevada segment had an increase in the number of deer killed in deer-vehicle collisions after the sign and flashing lights were installed and activated. In contrast, at the second Nevada segment there was a decrease in the deer killed. By combining the two segments, the overall number of collisions before the installations did not change significantly when compared with the collisions after the installations. The number of collisions was very small at the second segment, which weakens the second analysis. Looking at all of the NDOT collision data from October 1998 through April 2004, the annual mean was 47.5 with a standard deviation of 40.0. With such a large standard deviation, a more tightly designed control experiment is needed to determine whether this countermeasure is effective.

Since this joint study was completed, the NDOT and NDOW professionals concerned with US 93 have little confidence in this deer warning system that was installed in the fall of 2001.

5.0 EVALUATION OF COUNTERMEASURES

5.1 OVERVIEW

The recommended countermeasures that will be evaluated for this research project are an attempt to reduce the collisions between deer and vehicles on segments of US 93 and I-80, which are in the path of major deer migration activity. Approximately one-half of an estimated 10,000 deer population in the Jarbidge Mountains and Wilderness migrate across one or both of these highways twice a year. Over a decade, approximately 3500 deer are killed, which is significant considering the size of the deer herd. Below are locations where deer are more likely to be killed. Additionally, countermeasures identified from the literature review that may reduce the deer-vehicle collisions are discussed and evaluated on the context of the recommended locations. Finally, several recommendations are presented for analysis in Section 6.

5.2 RECOMMENDED LOCATIONS

Based on the five years of collision data there are several locations along US 93 and I-80 that merit attention. They are:

1) U.S. 93 MP 82-85 (inclusive) with 75 reported deer kills, plus an estimated 190 unreported
2) U.S. 93 MP 91-96 (inclusive) with 90 reported deer kills, plus an estimated 225 unreported
3) U.S. 93 MP 121-127 (inclusive) with 126 reported deer kills, plus an estimated 315 unreported
4) I-80 MP 94-98 (inclusive) with the reported number of deer kills not available, but is close to 125 including probable unreported kills

These locations have significant cut-sections that would allow for the construction of less expensive wildlife overpasses versus other sites. Additionally, the cut-sections will provide a natural approach for deer using the overpass structures.

5.3 POSSIBLE COUNTERMEASURES FOR EVALUATION

The literature review revealed only one ‘effective’ countermeasure - the wildlife grade separation and six countermeasures of ‘promise.’ These countermeasures are listed below together with comments regarding whether they have been used in Nevada. If so, discussion is included regarding the Nevada experience.

5.31 Wildlife Grade Separations with Exclusionary Fencing and Vegetation

To-date Nevada has not utilized any wildlife grade separations. Nevada Department of Wildlife has expressed interest in the installation of several overpass structures based on deer kill experience and site terrain where substantial cut sections exist. For US 93, the sites are in the vicinity of MP 83, MP 94 and MP 123, which correspond to the high deer-vehicle collision locations. There are two sites of interest on I-80 near MP 94, and MP 97. An alternative to site MP 97 is MP 98.5. Even if several wildlife overpasses receive funding, it seems reasonable to construct one overpass and evaluate its features, site, etc. before embarking on the construction of other overpasses.

5.32 Deer Crossing Warning Signs Activated during Migration

Currently, as documented earlier in this report, standard warning signs for motorists are being used throughout Nevada. Due to the relatively large traffic volumes and high operating speeds on I-80, Nevada Department of Transportation, in cooperation with Nevada Department of Wildlife, are utilizing ‘deer crossing warning signs activated during migration’ on I-80. The Nevada Department of Wildlife advises Nevada Department of Transportation when the deer migration occurs. On US 93, to warn motorist of deer crossing the highway, there are warning signs with flashers. No formal attempt has been made to determine any statistical significant change in collision after these warning devices went into service on I-80. For US 93 there was a joint study with Idaho and Utah that concluded such devices were effective; however, when only using Nevada data that conclusion was not validated.

5.33 Deer Crossing Warning Signs Activated by Presence of Deer

To-date Nevada has not utilized any warning signs activated by the presence of deer, but has been involved in a ‘pooled’ funded project to install and evaluate such systems. The two installations were not successful because of technological, management, climate, and other problems.

5.34 At-grade Crossings with Exclusionary Fencing and Warning Signs

To-date Nevada has not utilized any of these at-grade crossings.

5.35 Roadside Reflectors

Another countermeasure that has been used in Nevada is the roadside reflector. They were placed along US 50, a commuter route east of Carson City, to reduce the number of horse-vehicle collisions. While the reflectors, with red lenses, were in place for three years, the number of such collisions declined and the vendor representatives declared the reflectors to be effective. The reflectors had been removed for a construction project to widen the highway. However, during the time the reflectors were in place, the Nevada Department of Agriculture began removing horses from the corridor, which diminished the apparent effectiveness of the red reflectors. Additionally, the number of collisions before and after the installation of the reflectors is so small that formal statistical significance cannot be validated.

5.36 Roadway Lighting

To-date Nevada has not utilized any roadway lighting to help drivers see deer on the roadway at night; however, there is power available at the Pequop Summit on I-80, near MP 96. Consequently, this countermeasure could be utilized if the illuminaries can be obtained for a minimal cost.

5.4 COUNTERMEASURE EVALUATION

There were several possible countermeasures selected for analyzing and possible implementation in the field to determine how effective they would be in reducing deer-vehicle collisions. They are:

5.41 Roadside Reflectors

Install and evaluate **roadside reflectors** with blue lenses on a 2-mile section within the MP 83-85 segment for a period of 2 years. This location was chosen because it is closest to

Wells and will be more convenient and economical to hire people to clean the reflectors. There appears to be sufficient right-of-way to provide the 30-foot clear zone. The material cost of the reflector system would be approximately $15,000. However, dust must be removed regularly; and for research purposes, bags will need to be purchased and placed over the reflectors, alternating on one-half of the reflectors each week or two during the high migration periods. Manpower costs are not known at this time and would be expensive due to the remote location. Additionally, effective supervision of such research activities on US 93 from Carson City would be difficult. Because of the inconclusive findings from the literature, the remote nature of the location, winter maintenance issues especially snow removal, experience on US 50 in Nevada, and recommendations of other Nevada state agencies, this countermeasure was deleted from further consideration for field experimentation.

5.42 At-Grade Crossing with Exclusionary Fencing, Warning Signs with Flashers, and 'Cattle Guards' Across the Highway

At grade crossing with exclusionary fencing, warning signs with flashers and 'cattle guards' across the highway is a variation of the at-grade crossings with exclusionary fencing and warning signs. The concern with an at-grade crossing without cattle guards, steel or painted, is that some deer will tend to wander off the deer crossing and become trapped between the exclusionary fencing and the highway. Consequently, deer-vehicle collisions would be more likely without the cattle guards. These guards may need to be wider than the 7'3" in the NDOT standards. The width will probably need to be doubled and length would need to be approximately 26 feet (roadway width). Either MP 92-93 or 95-96 would be good segments to consider for this type of crossing. The cost of this type of countermeasure is approximately $200,000 with steel cattle guards and $150,000 with painted cattle guards. Due to the cost of steel cattle guards and their short life span, painted cattle guards were preferred. If the painted cattle guards are not effective, deer could be trapped inside the exclusionary fencing. Another concern is that the drivers will not see deer regularly enough and would, therefore, ignore the warning signs/flashers. This countermeasure was deleted from further consideration for field experimentation.

5.43 At-Grade Crossing Area with Exclusionary Fencing and Animal Detection Devices

Install and evaluate for 2 years an **at-grade crossing area with exclusionary fencing and animal detection devices** near MP 95 on I-80. It would likely involve a roadway section approximately one-half mile in length with exclusionary fencing. Depending on the type of animal detection devices and amount of fencing, this will cost approximately $300,000. Because of the inconclusive findings from the literature with the technological, management, climate and other problems, and remote nature of the location to monitor new technology, this countermeasure has major limitations.

5.44 High-Level Luminaries

Install and evaluate for 2 years **high-level luminaries** near MP 96, Pequop Summit. Electrical power is already available and District I plans to surplus four such luminaries that, at a reasonable cost, could be relocated to District III at Pequop Summit. The cost will be approximately $30,000.

5.45 Overpass Structure with Exclusionary Fencing and Vegetation

Install and evaluate for 2 years an **overpass structure with exclusionary fencing and vegetation**. The location with the highest collision rate is in this section, MP 121-126 on US 93; consequently, the vicinity of MP 123 would be a good location for the overpass. The cost for a concrete arch overpass (48’ long x 165’ wide) is approximately $2.8 million. In Appendix B an economic analysis of a wildlife overpass within this segment on US 93 had the Net Present Worth of approximately $4.5 million and a Benefit-Cost Ratio of about 2.6. It is estimated that the other possible sites for an overpass on US 93 and I-80, with fewer collisions, will have a positive Net Present Worth and a Benefit-Cost Ratio greater than one.

6.0 RECOMMENDATIONS

6.1 RECOMMENDATIONS

There were several recommendations resulting from this research report that relate to the goal of identifying specific countermeasures to reduce the number of deer killed on Nevada highways. The recommendations included:

1) Construct and evaluate an **overpass structure with exclusionary fencing and vegetation** at a high collision location on US 93. This countermeasure appears to be the only effective means to reduce deer-vehicle collisions at this time. The best location for an overpass will require more field review and some preliminary design. The total cost of such a structure will be approximately $2.8 million in 2006 dollars.

2) Since it will require a few years to develop an overpass structure, another recommendation is to install and evaluate an **at-grade deer crosswalk with exclusionary fencing and escape gateways, deer-warning signs with flashers, sensors to detect animals, and painted cattle guards** at a high collision location on US 93. Such a system would cost approximately $300,000 in 2006 dollars. Because of the limited success with these systems, careful management of project planning, which includes design, installation, maintenance, and monitoring is essential for this countermeasure.

3) Install and evaluate **high-level luminaries** near MP 96, Pequop Summit using surplus luminaries. Such an installation is expected to cost approximately $30,000 in 2006 dollars.

6.2 POLICY RECOMMENDATIONS

There are also policy recommendations resulting primarily from the literature search of this research project that would likely affect NDOT at the program level.

1) As a part of the environmental process for major projects, formal wildlife connectivity analysis should be conducted.

2) Wildlife migration data will need to be developed for corridor studies.

3) Bridge, culvert, and tunnel construction, and reconstruction projects should be designed to accommodate wildlife migration patterns.

4) For improvements initiated by the Districts, contact with NDOW should occur in the event the scope of the District improvements can be altered to help reduce vehicle collisions with wildlife.

5) Initiate a comprehensive, statewide, big game-vehicle collision reporting system with all appropriate public safety, transportation, and natural resource agencies involved with data collection. Have database maintained by NDOT.

7.0 IMPLEMENTATION ISSUES

The implementation of the research recommendations is constrained by several issues.

The first issue addressing implementing recommendations is the source of funding. Since the recommendations affect the mission of two state agencies, a joint funding arrangement between NDOT and NDOW is appropriate. NDOT will address the high benefit-cost ratio by exploring funding from the NDOT Highway Safety Improvement Program that is supported by federal highway safety funds. Additionally, some funding could be requested through NDOT's normal project selection process where it would compete with other project requests. For NDOW, specific project funding would need to be requested though its budgeting process.

The cost estimates for the countermeasures will need to be refined once specified sites are selected.

Any recommendation, that includes exclusionary fencing, needs a special analysis to address the land ownership issues and the presence of domestic livestock that may use the deer crossings to escape from their owners. Permission of property owners will be needed for placement of exclusionary fencing outside the highway right-of-way. Additionally, differential animal fencing, to prevent domestic animals from using the crossings, may be required. Finally, a mechanism, i.e. fencing, will be needed to prevent unauthorized vehicles and equipment from using wildlife grade-separated crossings.

The level of communication and discussion at several levels that has provided coordination between NDOW and NDOT to reduce big game vehicle collisions needs to continue. This communication will be needed throughout the development of any countermeasures that are implemented from conceptual design, including location, through detailed engineering. Thus, the requirements and priorities of each department can be effectively integrated into countermeasures that are implemented.

The installation of a deer crosswalk would require several special considerations. The use of painted cattle guards may not be sufficiently effective in channeling the deer within the crosswalk; consequently, ample escape sections are needed inside the exclusionary fence to allow the animals to exit the roadway area and to prevent a kill zone near the deer crosswalk. When using signs that would be activated during migration, a more effective means of activating warning signs with flashing beacons should be used. With the careful selection of sensors for detection, beacons on warning signs would be activated when larger wildlife is near the roadway. This is a major caution for the detection system. The several problem areas mentioned previously need to be addressed through careful project planning including design, installation, maintenance, and monitoring.

The availability of collision data may be a significant problem to this research project. For example, the collision data for I-80 contains reported deer-vehicle collisions, but does not contain the number of deer killed; and the collision data for US 93 includes both collisions and deer fatalities. Recently NDOT has initiated a new form and process for reporting animal kills on state maintained roadways. Because the statewide crash reporting system is under revision, data since 2003 must be developed manually. Consequently, recent crash data is very difficult to attain. Unique methods of data analysis may be required.

The maintenance and monitoring requirements and responsibilities will need to be specified and budgeted prior to the installation of any countermeasure.

8.0 APPENDICES

8.1 APPENDIX A
REFERENCES

Conover, Michael R. *Monetary and Intangible Valuation of Deer in the United States, Economics* and Wildlife Damage, Wildlife Society Bulletin, 25(2):298-305, 1997.

Conover, Machael R., William C. Pitt, Kimberly K. Kessler, Tami J. DuBow, and Wendy A. Sanborn. *Review of Human Injuries, Illnesses, and Economic Losses Caused by Wildlife in the United States,* Wildlife Damage, Wildlife Society Bulletin 23(3):407-414, 1995.

Cox, Mike, *2004-2005 Big Game Status.* Nevada Department of Wildlife. 2005.

Danielson, Brent Jr., Ph.D., and Michael W. Hubbard, Ph.D. *A Literature Review for Assessing the Status of Current Methods of Reducing Deer-Vehicle Collisions, The* Task Force on Animal Vehicle Collisions for Iowa Department of Transportation and Iowa Department of Natural Resources, July 1998.

D'Angelo, Gino J., Robert J. Warren, Karl V. Miller, and George R. Gallagher. *Literature Review: Evaluation of Strategies Designed to Reduce Deer-Vehicle Collisions,* University of Georgia, June 30, 2004.

Dumas, Amy. *Request for Strieter Reflectors in Nye and Esmeralda Counties,* Letter August 26, 2004.

Evink, Gary L., *Interaction Between Roadways and Wildlife Ecology,* Transportation Research Board, National Research Council, Washington D.C., 2002.

Ford, Stanley G. and Sharon L. Villa. *Reflector Use and the Effect They Have on the Number of Mule Deer Killed on California Highways,* Caltrans Environmental Division and California Department of Transportation, Report No. 53-626004, Contract E90PD20, August 1993.

Gladfelter, Lee. *Effect of Wildlife Highway Warning Reflectors on Deer-Vehicle Accidents,* Iowa Highway Research Board, Boone, Iowa, Project HR-210, Pages 1-11, December 1984.

Gordon, Kelly M., and Stanley H. Anderson. *Evaluation of the FLASH (Flashing Light Animal Sensing Host) System in Nugget Canyon, Wyoming*. (Interim Report), Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, July 2001.

Gordon, Kelly M., and Stanley H. Anderson. *Mule Deer Response to an Underpass in Nugget Canyon, Wyoming,* (Interim Report), Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming, June 2003.

Grenier, Robert H. *A Study of the Effectiveness of Strieter-Lite Wild Animal Highway Warning Reflector Systems,* June 28, 2002.

Hedlund, James H., Paul D. Curtis, Gwen Curtis, and Allan F. Williams. *Methods to Reduce Traffic Crashes Involving Deer: What Works and What Does Not.* http://www.highwaysafety.org Insurance Institute for Highway Safety, Arlington, VA, October 2003.

Holmes, Mike. *Strieter Lights.* Letter March 17, 2005.

Huijser, Marcel P., Patrick T. McGowen, Whisper Camel, Amanda Hardy, Patrick Wright, and Anthony P. Clevenger. *Animal Vehicle Crash Mitigation Using Advanced Technology: Phase I Review, Design and Implmentation,* Western Transportation Institute, Montana State University, SPR-3(076), August 2006.

Knapp, Keith K., Cara Kienert, and Adrian Witte. *Statewide and Upper Midwest Summary of Deer-Vehicle Crash and Related Data from 1993 to 2003.* http://www.mrutc.org and http://www.deercrash.com. Midwest Regional University Transportation Center. Deer-Vehicle Crash Information Clearinghouse. University of Wisconsin-Madison, Madison, WI. SPR Project Number 0092-01-11; Report Number DVCIC – 03. December 2005.

Kay, Fenton, R. *Nevada Survey of the Economic Value of Trophy Big Game and Deer Harvest: 1984 though 1986.* Biological Bulletin #9. Nevada Department of Wildlife, Reno, Nevada. December 1988.

Knapp, Keith K., Xin Yi, Tanveer Oakasa, Wesley Thimm, Eric Hudson and Chad Rathmann. *Deer-Vehicle Crash Countermeasure Toolbox: A decision and Choice Resource*, Midwest Regional University Transportation Center, University of Wisconsin-Madison, SPR Project Number 0092-01-11, Report Number DVCIC-02, June 2004.

Knapp, Keith, Wesley Thimm, and Chad Rathmann. *Regional Survey of Deer Population, Vehicle Travel, and Deer-Vehicle Crash Information Collection and Management.* Midwest Regional University Transportation Center, University of Wisconsin-Madison, SPR Project Number 0092-01-11, Report Number DVCIC-01, April 2004.

Levy, Alex. *Where the Wildlife Meets the Road*, Public Roads ISSN #033-3735, USPS #516-690, May/June 2005.

Rea, Roy V. and Roy V. Rea Sr. *Of Moose and Mud*, Public Roads, (32-39), http//:www.tfhrc.gov, V0l 69, #2, September/October 2005.

Reeve, Archie F. and Stanley H. Anderson. *Ineffectiveness of Swareflex Reflectors at Reducing Deer-Vehicle Collisions, Wyoming* Cooperative Fish and Wildlife Research Unit, University Station, Laramie, Wyoming, Wildl.Soc.Bull. 21:127-132, 1993.

Schafer, James, Stephen Penland, and William P. Carr. *Effectiveness of Swareflex Reflectors in Reducing Deer-Vehicle Accidents in Washington State*, Washington State Department of Transportation, (Abstract), Presented to the Committee on Traffic Control Devices 64th Annual Meeting, A3A02, January 14, 1985.

Schwabe, Kurt A., Peter W. Schuhmann, Michael J. Tonkovich, and Ellen Wu. *An Analysis of Deer-Vehicle Collisions: The Case of Ohio.* Proceedings of the 3rd National Wildlife Research Center Special Symposium, Fort Collins, CO. August 1-3, 2000.

Sivic, Abid and Leonard E. Sielecki. *Wildlife Warning Reflectors,* Ministry of Transportation and Highways, Environmental Management, HE5620.W54 W5 2001, C2001-960033-X. http://www.th.gov.bc.ca/bchighways/publications/pubcat.htm. January 2001

Sullivan, Todd L. and Terry A. Messmer. *Perceptions of Deer-Vehicle Collision Management by State Wildlife Agency and Department of Transportation Administrators.* Wildlife Society Bulletin, 31(1):163-173, 2003

Sullivan, Todd L, Allan F. Williams, Terry A. Messmer, Laurie A. Hellinga, and Sergey Y. Kyrychenko. *Effectiveness of Temporary Warning Signs in Reducing Deer-Vehicle Collisions during Mule Deer Migrations.* Wildlife Society Bulletin, 32(3):907-915, 2004

TranSafety. *Roadside Wildlife Reflectors – Do They Work?* http://www.usroads.com/journals/rmj/9705/rm970504. Road Management & Management Journal Copyright 1997 by TranSafety. Accessed August 16, 2006.

Umbs, Rudolph M. *MUTCD's Response to Product Review of Strieter-Lite,* Letter October 20, 1995.

Ward, A. Lorin. *Roadside Management: Mule Deer Behavior in elation to Fencing and Underpasses on Interstate 80 in Wyoming.* Transportation Research Board, National Research Council, Record 859, 1982.

Waring, G. H., J.L. Griffis and M.E. Vaughn. *White-tailed Deer Roadside Behavior, Wildlife Warning Reflectors, and Highway Mortality.* http://www.sciencedirect.com/science?_ob=ArticleURL&-udi=B6T48-49NRS49-14W Department of Zoology, Southern Illinois University, Carbondale, IL. Pgs 1-2; October 2, 2003.

Watson, Mark and Jon Klingel. *Literature Summary: Assessing Methods for Reducing Deer-Vehicle Accidents.* New Mexico Wildlife Literature Review. http://www.wildlife.state.nm.us/conservation/habitat_handbook/Deer-VehicleAccidents.htm. Pgs 1-19; June 28, 2006.

Zacks, James L. *Roadside Design & Management: Do White-Tailed Deer Avoid Red? An Evaluation of the Premise Underlying the Design of Swareflex Wildlife Reflectors.* Transportation Research Board, National Research Council, Record 1075, 1986.

http://www.deercrash.com. Accessed August 8, 2006.

http://www.deertracking.com/archive/february02/index.html. Accessed July 27, 2006.

8.2 APPENDIX B
WILDLIFE OVERPASS ECONOMIC ANALYSIS

8.21 Economic Analysis

The purpose of this economic analysis is to determine some sense of the economics of such a large investment as a wildlife overpass. There were two means of expressing the results; namely, Net Present Worth (NPW) and a Benefit-Cost Ratio (B/C). For this analysis, the location of the over pass structure was assumed to be within the segment bounded by MP 125-127 inclusive on US 93. There is considerable data that was collected, but the several assumptions are listed first. Finally, a summary is provided.

8.211 Assuptions

1) With extensive exclusionary fencing (4 miles on each side), 90% of deer-vehicle collisions will be eliminated within the segment.
2) The number of reported deer-vehicle collisions is 29%, which was based on field collected along 10-mile segment of I-80 that included Pequop Summit by NDOW in the fall of 2005.
3) All older costs were adjusted to 2006 dollars based on Consumer Price Index.
4) The value of the wildlife overpass at the end of 50 years was zero.
5) The value of deer was based on the average of 2001-2005 data and included the cost of nonresident tags, travel, food, lodging, equipment, etc., incurred by hunters divided by the total number of deer killed by hunters.
6) The 2003 Utah vehicle damage cost ($1,574) was used because the 2002 statewide Nevada cost of $3500 was the average for all property damage for types of collisions and deer collisions are probably less severe, implied by the 29% reporting rate.
7) For the injury cost the 2002 statewide Nevada data for 'stuck animal' collision cost was reduced since 35% of animal collisions were animals larger than deer. The rural cost of $144,400 was reduced by 50% to $72,200.
8) The 2002 statewide Nevada data of $2,432,000 was used for fatal collisions.
9) The Upper Midwest data was used as the portion of fatal collisions. Nevada data had one fatal in five years giving a probability of 0.001, which was about 5 times higher than published data. The Nevada sample was too small to be reliable.

8.212 Basic Data

Collision Costs

- Damage (DC) - $6,803 (2006)
  - ($1,732 - 2003 Utah data adjusted to 2006)
  - ($4,452 - 2006 value of deer in Nevada.)
  - ($619 - 2006 value of hunters' travel, food, lodging, equipment, etc.)
- Injury (IC) - $81,270 (2006)
- Fatal (FC) - $2,737,521 (2006)

Probability of Collision (Portion of total accidents)

- Damage (PD) - 0.9591
- Injury (PI) - 0.0407 (Nevada data)
- Fatal (PF) - 0.00021 (Upper Midwest data)

Collision Data – 10.4/year (5 years for the 3 mile segment, annual amount increased by 3.5 because of the 29% reporting rate)
Capital Cost (CC) - $2,780,000
Structure - $2,500,000 (2006)
Fencing and vegetation - $175,000 (8 miles of fencing)
Backfill and Top Soil - $100,000
Maintenance Cost (MC) - $3,000 annually for vegetation and fencing maintenance
Interest Rate (i) - 4% (Based on the approximately average for the past 50 years)
Life of Project (n) - 50 years (Reinforced concrete bridge structure)

8.213 Model

NPW = {(DC)(PD) + (IC)(PI) + (FC)(PF)} (N) (PWF) – {CC + (MC) (PWF)}
PWF – present worth factor (i = 4%, n = 50 years)
N – number of collision reduced (90% reduction factor)

8.214 Calculations (All costs are 2006)

NPW = {6,803*0.9591 + 81,270 *0.0407 + 2,737,521*0.0002}(10.4*3.5*0.90)*21.48 – {2,780,000 + 3000*21.48)
NPW = {6,525 + 3,308 + 575}(32.76)(21.48) – {2,780,000 + 64,000}
NPW = 7,323,000 – 2,844,000
NPW = $4.48 million
B/C = 7,323,000/2,844,000
B/C= 2.57

8.22 Summary

There are two limitations regarding this analysis aside from the assumptions. A better estimate of the overpass structure capital cost will require preliminary design work based on a specific site. The intrinsic value placed on the loss of deer by the non-hunting public could be neither be determined nor incorporated in the economic analysis.

The wildlife overpass has the Net Present Worth of approximately $4.5 million and a Benefit-Cost Ratio of about 2.6. Clearly, wildlife overpass within the segment, MP 125-127 inclusive, on US 93 is economically feasible. There are other sites on US 93 with fewer collisions that will probably provide a positive Net Present Worth and a favorable Benefit-Cost Ratio as well. Finally, an overpass near Pequop Summit on I-80, may be economically feasible.

8.3 APPENDIX C
EVALUATION OF ROADSIDE REFLECTORS

8.31 Overview

Special attention was paid to the Strieter Corporation roadside reflector system for several reasons: the devices are inexpensive compared with deer crosswalks and overpass countermeasures, the devices are being used in many states and local agencies, and NDOT had installed them on US 50 near Carson City, the state capitol. This appendix discusses the US 50 experience first and then the experiences in other jurisdictions.

8.32 Nevada Experience

In March of 2002 the Strieter reflectors were installed on a 3-mile segment of US 50. After one year, in March of 2003, the reflectors were removed for a construction project that will widen the highway. While this installation of the reflectors was not a research project, the nighttime collision history was reviewed to see whether the reflectors were effective. For the three years prior to the installation, there were reported seven horse-vehicle collisions and one deer-vehicle collisions.

During the year the reflectors were in use, there were no reported deer-vehicle collisions. Consequently, many local residents, including the local representatives of Strieter claimed a successful application. Of course, such a claim is groundless. The number of collisions was too small for statistical analysis; more importantly, during the period of time the reflectors were in place, the Nevada Department of Agriculture was removing horses from the US 50 Corridor. Obviously, the number of horse-vehicle collisions should have declined regardless of the reflectors.

8.33 Experience Outside Nevada

Since the reflector devices have been in use for many years and used by many agencies, a number of reports have been published attempting to evaluate the effectiveness of roadside reflectors. Most of the reports acknowledge the difficulty with such evaluations. Some studies reported reductions in nighttime deer-vehicle collisions with reflectors in use while other studies indicated no reduction in such collisions. One such report came from British Columbia, Canada, (Sielecki, 2004) where the roadside reflectors are popular and they were installed on 16 roadway segments. The collision history was reviewed for many years for two of those sites and compared with sites without reflectors. The comparison showed no reduction in deer-vehicle collision. However, there were no experimental designs to deal with the numerous variables – deer herd population, deer migration patterns, climate, vegetation available to deer, land development, etc. Consequently, the provincial government initiated a longer term (4 to 5 years) study with better controls. Researchers in British Columbia also conducted a comparison study of the two popular reflector systems, Swareflex and Strieter (Sivic and Sielecki, January 2001). While the Swareflex devices generally provided more reflected light, the Strieter spacing layout of the reflectors was more effective. However, the report contained information about a vision test on deer that revealed the eyes of deer were more sensitive to blue/green light than white, red, and yellow. This suggests that the reflectors with lenses that produce light with wavelengths near 440 nanometers would probably be more effective.

The Strieter Corporation apparently hired a statistician (Griener, 2002) to analyze deer-vehicle collision data, which showed a remarkable decline in such collisions, 78% to 90%. This study made use of a Wilcoxon rank test. While the statistical methodology appeared sound, there were some limitations with the database. There were other data that were readily available in the literature that were not included in the Griener report; namely, 1) two sites on Highway 3 in British Columbia, 2) sites on Highway 101 in the State of Washington and 3) sites in California. Since all of the studies containing these data reported that the roadway reflectors were not effective, researchers would naturally be curious why these data and perhaps others were not used. The Griener report does not discuss any data limitations or qualifications. Given the numerous variables – deer herd population, deer migration patterns, climate, vegetation available to deer, land development, etc. that must be controlled, the best methodology in the literature to evaluate the roadside reflectors is the cover-uncover method. For this method, subsets of reflectors are alternately covered and uncovered at regular intervals, usually 2 weeks, during the migration period. The results of several cover-uncover studies are shown is Table C.1, which reveals that only one of these studies (Schafer, 1985) reported a statistically significant reduction in deer-vehicle collisions when the reflectors were uncovered.

The Strieter Corporation has criticized all of these reports, except Schafer, for using the old installation method and lacking proper installation, maintenance, and monitoring. The Strieter critical work did not mention the Ossinger's study. The evaluation by Shafer was in the early 1980s; consequently, the Swareflex reflectors were used with the old installation method, and the Shafer report made no mention of contact with Strieter Corporation for instruction regarding proper installation, maintenance, and monitoring.

Table C.1 Summary of Cover-Uncover Studies

Author	Location	Duration	Collisions [Covered]	Collisions [Uncovered]
Woodard, et al. 1973	CO	24 weeks	8	11
Armstrong 1992	Ontario, Canada	54 weeks	16	14
Ford, et al. 1993	Chester, CA	3(1) years	93(40)	129(41)
Reeve, et al. 1993 (test)	Nugget Canyon, WY	NA	64	126
Reeve, et al. (control)		NA	62	85
Schafer, et al. 1984	Spokane, WA	3 years	52	6
Ossinger 1991	Discovery Bay, WA	3 years	21	20
Woodham 1991	Denver, CO	3 months	0	0
TOTAL			295(242)	371(283)

Notes:

1. *Woodard study counted all collisions, not nighttime.*
2. *Ford reported a potential problem of bias with the field data and so a new team was hired for the third and last year of the study. The third year of data is shown in parentheses.*
3. *Reeve study included a test section (first line) and a control section (second line) to determine whether the two sections had similar number of collisions.*
4. *Woodham report study was terminated after 3 months due to cost of fieldwork, etc.*

One concept of successful scientific experiments is that they can be duplicated; however, the favorable result of the Schafer work has not yet been duplicated. In fact, Ossinger (1991) expected to have similar results as Schafer on US 101 near Discovery Bay, Washington; but, it did not occur.

Special criticism by Strieter was directed toward the California report (Ford, 1993) as a 'self fulfilling prophecy' because the researchers, according to Strieter, were confident that the reflectors would not be effective. The Ford report readily admits there were data collection problems that could adversely bias the results. Consequently, the fieldwork duties were given to others in an attempt to correct the situation. Comparing the first two years of data against the last year of data, see Table C-1, there is reason to conclude that error or bias had been introduced. Nevertheless, the researchers need to be given credit for recognizing the problem and taking steps to eliminate it. Given that, there is no reason to omit the third year of data, especially since the literature review found that no one else has been able to duplicate the Shafer results using the same technique.

8.34 Conclusions

Despite the frequent use of the roadside reflectors, the claim that they are effective in reducing deer-vehicle collisions could not be established scientifically from the literature or the Nevada experience.

Kenny C. Guinn, Governor

Nevada Department of Transportation
Jeff Fontaine, P.E. Director
Tie He, Research Division Chief
(775) 888-7220
the@dot.state.nv.us
1263 South Stewart Street
Carson City, Nevada 89712