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RH: Getting deer off of the road

Getting Deer off of the Road: A Better Way

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Key Words: deer, economic assessment, escape ramps, highway, jumpouts, mitigation, net present value, right-of-way, roads, wildlife.

Abstract: One-way steel escape gates with closely spaced tines have been the standard for most U.S. Departments of Transportation to allow deer (Odocoileous sp.) and other animals to escape the road right-of-way (ROW) when exclusion highway fencing is used (F. Wright, Utah Department of Transportation, personal commun.). However, observations of deer behavior suggest that squeezing through closely spaced tines is done only under duress. We investigated the effectiveness of an alternative escape method, viz., earthen one-way ramps placed against the ROW fence on two highways in northern Utah. Our results showed that

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the escape ramps were used by mule deer on average 8.2 times more frequently than one-way gates. Additionally, a benefit-cost analysis demonstrated that the ramps were cost-efficient both in the immediate term and for the typical life of a ramp (10 years). Results of the benefit-cost analysis indicated that when results were grouped for SR 91 and SR 40, net present value (NPV) was positive at all potential mortality levels averted for both gates and ramps, but when results were separated by roads, NPVs for gates were negative when mortality level averted was low. The NPV for ramps is positive and considerably higher than that for gates at all mortality levels. We argue that Departments of Transportation should consider earthen escape ramps the standard structure for allowing deer and other large animals to escape the right-of-way on roads with typical high (~2.4 m) exclusion fencing.

Key Words: deer, escape ramps, highway, jumpouts, net present value, right-of-way, roads

Between 1900-1976, the U.S. road system almost doubled in length (Federal Highway Administration 1979). Expansion has continued, with 88,000 km (55,000 miles) of new roads added during the period 1987-1997, resulting in ~6.3 million km (~ 3.9 million miles) of public roads; 80% are in rural areas (Forman et al. 2003). Virtually all urban and rural roads are owned and operated by local, state, or federal governments. Although gaining an exact estimate is difficult, about 600,300 km (~373,000 miles) of roads serve the National Forest system (The Lands Council 1998, Williams 1998), not including an additional 96,560 km (~60,000 miles) of roads apparently not in the Forest Service inventory (Bissonette and Storch 2003). Recent estimates put BLM road mileage at 131,966 km (~82,000 miles), National Parks and Parkways at 13,679 km (~8,500 miles), National Wildlife Refuges at

11,265 km (~7,000 miles), and Bureau of Indian Affairs mileage at 38,624 km (~24,000 miles) (Federal Highway Administration 2002). Clearly Americans live on a roaded landscape. Americans currently own ~230 million motor vehicles and total annual vehicle miles traveled (VMT) has grown from 260,516 million during the period 1950-1960 to 2,144,362 million VMT by 1990; during 2001, Americans drove 2,781,462 million miles, an increase of 29.7% from 1990 (Bureau of Transportation Statistics 2004). At the same time, the number of licensed drivers in the U.S. increased from 167,015,254 in 1990 to 191,275,719 in 2001 (14.5%). Vehicle Miles Traveled have increased more rapidly than the number of licensed drivers (Federal Highway Administration 2003) and faster than the U.S. population growth rate (13.2% for the time period 1990-2000). In Utah, the trend is even more striking. Vehicle Miles Traveled in Utah rose from 14,646,000 in 1990 to 23,452,000 in 2001, an increase of 60.1%, while the number of licensed drivers increased from 1,046,106 to 1,495,887 over the same period, an increase of 43.0% (Bureau of Transportation Statistics 2004). The Utah population rose 29.6 % from 1990-2000. With increased traffic volume on an expanding road system, the probability of animal-vehicle collisions has increased. Several studies have shown that traffic volume was positively correlated with animal mortality on roads (Fahrig et al 1995, Joyce and Mahoney 2001). For example, Inbar and Mayer (1999: p. 865) stated that “Of all the traffic volume data sets, mean nighttime traffic generated the only significant correlation with road kill”. Vehicle speed also has long been implicated in animal mortality on roads (Dickerson 1939). Case (1978) and Rolley and Lehman (1992) reported that vehicle speed was significantly correlated with road mortality. Road mortality of animals, although influenced by driver speed and traffic volume, is also influenced by the behavior of animals who respond to environmental variables adjacent to the road. The presence of cover close to the road, migration corridors, and natural travel routes adjacent to the road all have been implicated in animal-vehicle crashes (Hubbard et al. 2000).

The impact of the roaded landscape on wildlife is manifested by both direct effects (e.g., animal mortality) and indirect effects. Indirect effects include habitat loss and landscape fragmentation, as well as barrier and roadside zone effects (Bissonette 2002). Direct effects are most noticeable for larger species; e.g., deer, elk (*Cervus canadensis*), moose (*Alces alces*) and larger carnivores, but also impact smaller species. Data for the ‘barely noticed’ species tend to be much more limited in area coverage. Additionally no concerted or organized attempt has been made to extrapolate existing values nationwide. Nonetheless, the number of smaller, less noticed species killed on roads is formidable (Ehmann and Cogger 1985, Ashley and Robinson 1996).

In the U.S., data tend to be better for large animal road mortality, thus skewing our perception. Data for both white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) suggest an estimated 720,000 animals killed on U.S. roads each year (Conover et al. 1995). Not all animals remain visible after being hit. Romin (1994) estimated that as many as 50% of deer hit leave the road surface and may never be counted. Decker et al. (1990) suggested that only 1/6 of deer hit may be counted. Additionally, Allen and McCullough (1976) estimated that 92% of deer hit died as a result. Assuming the generality of these results, conservatively more than 1.2 million deer may die annually on U.S. roads. The larger wildlife species (deer, elk, moose (*Alces alces*), caribou (*Rangifer tarandu*s), and large carnivores) pose the most risk to driver safety and result in higher auto damage and higher human injury rates. In the Upper Midwest (Wisconsin, Minnesota, Iowa, Illinois, Michigan) Knapp (University of Wisconsin, pers. commun.) documented 125,801 deer-vehicle crashes in 2003 resulting in vehicle damage of ~ $214 million, but more importantly, in 45 human deaths and 4,650 injuries; annually >200 people on average are killed in animal-vehicle crashes in the U.S. (Conover 1997).

Many mitigation measures have been tried in an effort to reduce deer-mortality along highways. These measures include increased highway lighting (Reed 1981), lighted animated deer warning signs (Pojar et al. 1975), swareflex reflectors (Gladfelter 1982, Schafer and Pendland 1985, Waring et al. 1991, Reeve and Anderson 1993), intercept feeding (Wood and Wolfe 1988), ultrasonic warning whistles (Romin and Dalton 1992), at-grade deer crosswalks (Lehnert 1996, Lehnert et al. 1998), and game-fencing (Falk et al. 1978, Ward 1982, Ludwig and Bremicker 1983, Feldhamer et al. 1986). Common wisdom holds that properly maintained exclusion fencing along road ROWs is the most effective of these measures. However, if fences are installed, overpasses or underpasses along with ROW escape structures must be included as part of a linked mitigation strategy to allow animal movement and to maintain some measure of permeability across the roaded landscape.

One-way escape gates typically have been installed along game-fenced roads to allow trapped deer to escape the ROW to the non-highway side of the fence (Fig. 1A). Lehnert (1996) found that only 40/243 (16.5%) of the deer that approached one way gates on SR 40 in Utah proceeded to jump through the gate to exit the ROW. Reed et al. (1974) estimated that approximately 223 deer used one-way gates to exit the ROW along I-70 near Vail, Colorado during 1970-1972, though data regarding the number of approaches without successful passage was not given. Earthen escape ramps are also used to enable deer to exit the highway ROW (Fig. 1B). Earthen ramps are sloping mounds of soil placed against a backing material approximately 1.5 m in height and constructed on the ROW side of the fence. The taller ROW fence (~2.4 m) is lowered at the ramp site and forms an integral part of the jump-out that allows deer to jump to the non-highway side of the fence. The jump-out is not a deterrent for deer because they are accustomed to traversing and maneuvering over steep terrain. The vertical drop off on the backside of escape ramps is designed to preclude deer from gaining access to the ROW from the non-highway side of the fence. Approximately 15-20 earthen escape ramps were constructed along I-80 near Laramie, Wyoming in the mid-1980’s. Although their effectiveness has not been quantified through rigorous study (R. Guenzel, Wyoming Department of Fish and Game, pers. commun.), tracks often were seen on these ramps (B. Hailey, Wyoming Department of Fish and Game, pers. commun.). There is also one earthen ramp along SR 191 near the northern city limits of Jackson Hole, Wyoming that was designed specifically for use by elk from the National Elk Refuge. Other ROW escape ramps recently have been built in other states. Providing deer with a quick and effective way to exit fenced ROWs is important. A 16.5% effectiveness rate for steel one way gates did not appear sufficient to significantly reduce deer road mortality; therefore we wanted to determine if earthen escape ramps might be more effective in allowing deer to exit the highway ROW. Because earthen ramps are similar to natural topographic features that deer regularly negotiate, we predicted that this mitigation configuration would be more amenable to animal passage than the traditional steel gates (Fig. 1A).

We conducted a benefit-cost analysis to determine whether the costs associated with the installation of escape ramps would be offset by projected decreases in the losses associated with deer-vehicle collisions and to compare the effectiveness of ramps versus gates. Deer value, vehicle insurance claims, cost of ramp and gate installation, and projected decreases in deer mortality were used to assess the cost-effectiveness of ramp and gate installation.

STUDY AREAS

Two game-fenced highways in Utah with a relatively high incidence of deer-vehicle collisions were selected as study sites: 1) SR 40 near the Jordanelle Reservoir and 2) SR 91 in Sardine Canyon between Logan and Brigham City (Fig. 2). The SR 40 study site was located near the Jordanelle Reservoir, approximately 6 km southeast of Park City in Summit county. SR 40 is a four-lane divided highway with a speed limit of 65 mph. This highway has been the focus of prior studies on deer-highway mortality and mitigation measures (Romin 1994, Lehnert 1996, Lehnert et al. 1998). Mule deer typically occupy the study area year round. However, during severe winters deer migrate into the lower valley areas where forage is more accessible. During milder winters, deer confine most of their activities to south-facing slopes.

The Sardine Canyon area encompassed a section of SR 91 located in Box Elder County just south of Cache County. SR 91 is an undivided four-lane highway. When this study was initiated the speed limit was 65 mph, however just prior to the termination of the study the speed limit was lowered to 60 mph. The area is mountainous with elevations ranging from 1,477 - 1,786 m. Mule deer use this area during all four seasons, however summer use is limited. Deer usually move to higher elevations to forage in the summer, and then back to lower south-facing slopes with access to forage during winter, when snowfall is heavy.

METHODS

Description of mitigation techniques

In 1994, exclusion fencing (~2.4 m), at-grade crosswalks (Lehnert 1996), and one-way escape gates were installed from milepost (MP) 4.0 to MP 8.1 on SR 40 to reduce deer vehicle collisions. Crosswalks were designed to allow normal seasonal and daily movements of deer by directing them across the highway in well-marked locations where motorists could anticipate their presence. The crosswalk system allowed deer to access the roadway and they occasionally browsed along the ROW. Structures that offered an escape for deer trapped on the ROW between crosswalks were necessary to facilitate their exit from the ROW. Paired one-way escape gates were installed at each crosswalk at the same time that the deer fence was built. Deer mortality along SR 40 decreased 42.3% on a four-lane highway and 36.8% on a two-lane highway, subsequent to the installation of game-fencing and crosswalks when compared to previous years however deer-vehicle collisions still occurred frequently (Lehnert 1996). In order to further reduce deer-vehicle collisions, the Utah Department of Transportation (UDOT) installed earthen escape ramps on SR 40 in 1997 as an alternative to one-way gates. Construction was completed on three ramps in June 1998 and five additional ramps were constructed in August 1998. All ramps were located within the game-fenced segment of SR 40 between MP 5.0 and MP 6.5 (Fig. 2).

State Route 91 in Sardine Canyon has ~2.4 m fencing and one-way escape gates in place from MP 5.0 to MP 16.5. Four culverts are present along this section of the highway and deer utilized these to travel beneath the highway corridor. Observations along SR 91 showed that despite the placement of game-fencing and underpasses, approximately 50 deer were killed in 1996 between MP 6.0 and MP 10.0 (R. Schultz, Utah Division of Wildlife

Resources, pers. commun.). In an effort to reduce mortality, nine earthen escape ramps were installed during October 1997 between MP 7.0-9.0 where deer mortality was concentrated (Fig. 2).

Assessing deer use of earthen escape ramps and one-way escape gates

To quantify use of earthen escape ramps and one-way escape gates, topsoil was used to construct track beds at the top of each ramp and on both the highway and non-highway side of each one-way gate. Obtaining accurate counts on the track beds proved difficult due to the dry soil conditions associated with the track beds. To remedy this problem and facilitate reading of the track beds, 2-3 gallons of vegetable oil were mixed with the soil of the track beds, resulting in soil characteristics that showed distinct hoof prints. Oiled track beds were easy to maintain, lasted throughout the field season, and were reliable in obtaining accurate counts of deer use of the ramps and gates.

Gate and ramp data were collected concurrently during summers 1998 and 1999 on both SR 91 and SR 40. Track beds were established (Table 1) at three earthen escape ramps and four one-way gates along SR 40 in July 1998 and monitored until October 1998. One-way gates were installed in pairs and tracks were counted at both gates in the pair. The one-way gates and ramps on SR 40 were all located between MP 5.0 – MP 6.5, allowing deer equal access to both types of escape structures and thus avoiding bias that might be associated with different deer densities in different locations. Track beds were established at seven earthen ramps and eight one-way gates along SR 40 in May 1999 and monitored until October 1999. Track beds were established at nine earthen return ramps and ten one-way gates on SR 91 and monitored for use from June 1998 until October 1998 and from May 1999 until October 1999. All ramps and gates were located between MP 7.5 – MP 9.0.

We counted the number of deer using the ramps by counting the number of trails made by track impressions on the beds. Trails that ended at the top of the ramp were considered a successful cross. Ramp use was grouped into the following categories:1) none, 2) one cross, 3) two crosses, and 4) 3 or more crosses. The last category was used because of difficulties in ascertaining exactly how many deer used the structure when more than two deer trails were present on the ramp. Track beds were constructed on both the highway and non-highway side of each one-way gate. Gate effectiveness was defined by the number of animals that successfully used the structure to exit the highway ROW as determined by track trails on both sides of the gate. We recorded the number of approaches and passages, as well as attempted passages from the non-highway side of the gate. Track beds at gates and ramps were checked 2-4 times weekly during the summer months and the beds were raked smooth after each reading. We obtained kill data for Sardine Canyon from R. Schultz, Conservation Officer, UDWR for the period 1996-2001, and for SR 40 from the Utah Department of Transportation web site.

Benefit Cost Analysis

We conducted a benefit-cost analysis of escape ramps and escape gates for a 10-year period beginning in 1998, the first year that all ramps were in place. All calculations are in 1998 dollars. Total project life was set conservatively at 10 years because ramps installed in Utah in 1997 showed no signs of deterioration 7 years later. Steel gates require little maintenance. Annual discount and inflation rates of 6% and 3% were used. The measure of investment performance used was net present value (NPV), the value of all benefits and costs discounted to the present and summed.

Benefits were defined as the value of the damage averted by deer using escape ramps or gates over the project's life. These values include the value of deer not killed on the ROW, and the value of vehicle damage averted. Dollar-quantified benefits associated with fewer human injuries and fatalities resulting from deer vehicle accidents were not included in this analysis, although approximately 4% of all DVCs result in human injury or death (Schwabe et al. 2002).

Deer Value.--The total value of a deer saved by ramp installation is difficult to assess. The value of an individual deer must be established, and the number of deer not killed as a result of the ramps being available must be determined. Each deer is not equally valued, because differences in age, sex, and condition can affect how humans value deer. Further, the approach used to value deer can result in large discrepancies in value. Estimates in the literature regarding the value of a mule deer range from $64 (Keith and Lyon 1985) to $1,468 (Romin and Bissonette 1996). Loomis et al. (1989a,b) used contingent valuation to estimate the value of an average mule deer at $217 (1998 adjusted dollars using the Consumer Price Index (CPI)[3]. This value represents the value of a deer over and above the cost to a hunter of obtaining a permit, traveling to the site, etc. We used this value in the analysis.

Data on the number of deer that become trapped on a game-fenced ROW and are involved in a vehicle collision cannot be collected by any reasonable means available, short of camera surveillance along the entire road segment, which is prohibitively expensive and

[3] The CPI inflation calculator uses the average Consumer Price Index for a given calendar year. This data represents changes in prices of all goods and services purchased for consumption by urban households. This index value has been calculated every year since 1913.

often impractical. The number of trapped deer involved in collisions is dependent upon numerous factors including; average daily traffic volume, traffic speed, fence length and integrity, weather conditions, and number, location, type of escape structure, and deer exposure. Here, deer exposure is defined as the probability of a deer accessing the ROW and road surface. The effectiveness of installing the earthen escape ramps on SR 91 and SR 40 was determined by using the number of successful ramp crossings and 3 potential deer mortality levels to generate projected losses averted. Crossing data were collected during the summer months (Table 1) but we allowed these data to represent a full year of crossings. More crossings would have occurred during the rest of the year, so our estimates of annual deer crossing are conservative. We made the assumption that at least some of the 375 deer that used the ramps and some of the 46 deer that used the gates to exit the highway ROW throughout the duration of the study would have been killed on the road had these structures not been in place. We evaluated three potential levels of mortality (2%, 7%, and 15%) that may have occurred if deer that crossed to safety by using the ramps or gates had instead been hit on the roads. These percentage values were adjusted by the number of successful deer crossings at each location to generate potential deer mortality numbers (e.g., for ramps on SR 91, 183 successful crosses x 2% equals 4 deer; similarly, on SR 40, 192 successful crosses x 15% equals 29 deer). As we have no way to project the number of deer that will use the ramps or gates over the decade of the project, we assumed that the number of deer calculated from the mortality percentages were constant for each of the 10 years.

Vehicle Damage Value.-- In 1992 big-game vehicle damage claims averaged ~$1,200 per incident in Utah (Romin 1994). We adjusted the vehicle damage claim amount to 1998 values for ~$1,320 per deer-vehicle collision. To check the vehicle damage valuation, we used independent 2003 data from the Deer Vehicle Crash Information Clearing House (DVCICH) data base to estimate values for Utah. This yielded an average CPI adjusted cost of ~$1,506 per vehicle, a difference of $186 per accident (14.0%). We used the conservative estimate of $1,320. Vehicle damage costs will no doubt continue to increase.

Total Value of Damage Averted.--Summing the deer value ($217) and the vehicle damage costs ($1,320) yielded an average loss associated with each deer-vehicle collision of $1,537. The number of deer mortalities was multiplied by the average economic loss of a deer-vehicle collision ($1,537) to obtain an estimate of the mitigated benefits of installing the ramps or gates for each year of the project.

Costs.--Costs included the cost of constructing the escape ramps or gates and associated annual maintenance costs, if any. Actual construction costs of ramps along SR 91 were approximately $225 each (R. Schultz, UDWR, personnel commun.). However, this was an exception to the usual cost of $500 per ramp, including materials and labor (B. Bonebrake, Utah Division of Wildlife Resources, personal commun.). We used the $500 cost per ramp to facilitate extrapolating our results to other situations. Very little (if any) maintenance has been done on the ramps since their installation, but we assumed annual maintenance costs of $250 for the life of the ramp. Installation of gates was estimated to be $325 (R. Miller, Utah Department of Transportation, pers. commun.). Little or no maintenance is required or done once gates are in place.

RESULTS

Ramp Effectiveness: Gate vs. Ramp Use

Each steel gate track bed along SR 40 was checked 40 times over the course of the study. Sixty-three deer approached the gate from the ROW and 31 (49.2%) of these deer used the gate to exit the ROW. Each one-way gate track bed along SR 91 in Sardine Canyon was analyzed 52 times over the study period. Forty-five animals approached the gate from the ROW and 15 (33.3%) passed through the gate. None of the deer that approached the gates from the non-highway side of the fence passed through to access the ROW. We were unable to determine if any individual passed through the gate more than once, but if that happened, the percent crossing effectiveness we reported would be conservative. Regardless, these values are significantly higher than the 16.5 % reported by Lehnert (1996).

Track beds located on earthen escape ramps on SR 40 were checked 42 times during the study period. A total of 192 successful crossings occurred. Ramp track beds on SR 91 were checked 61 times during the study period: we recorded in 183 successful crossings. We were unable to determine the number of deer that approached the ramp and did not cross, hence we cannot calibrate an approach:cross ratio; however, we standardized data comparisons by calculating the number of gate and ramp *use days* during the study period, allowing a direct comparison between the use of earthen escape ramps and one-way escape gates. We calculated an index of use for each treatment (gates and ramps), study site (SR 40, SR 91), and year (1998, 1999) and compared treatment effectiveness using the following equations:

$$G_d = (N_o)\,(N_g) \qquad \text{Eq. 1;}$$
$$R_d = (N_o)\,(N_r) \qquad \text{Eq. 2;}$$
$$I_{ug} = (N_{tg} / G_d)\,10 \qquad \text{Eq. 3;}$$
$$I_{ur} = (N_{tr} / R_d)\,10 \qquad \text{Eq. 4;}$$

where G_d equals gate days, R_d equals ramp days, I_{ug} equals gate index of use, I_{ur} equals ramp index of use, N_o is the number of days in the observation period, N_g is the number of gates, N_r is the number of ramps, N_{tg} is the number of successful gate crossings in the observation period, and N_{tr} is the number of successful ramp crossings in the observation period.

Ramps were used much more frequently than gates on both SR 91 and SR 40 during both sampling seasons. The ramps on SR 40 were used approximately 7-9 times more frequently than the gates, while the ramps on SR 91 were used 9-13 times more frequently than the gates. When both seasons of use were averaged at both sites, ramp use was 8.2 times higher than gate use (Table 2).

Did Ramps Reduce Mortality?

The obvious question to ask is whether the ramps reduced deer mortality. At the Sardine Canyon site, where we and the Utah Division of Wildlife Resources collected data from 1998-2001 before and after the ramps were installed, mortality dropped by an average of 26.7%, from 37.5 to 27.5 deer killed per year (Fig. 3). Although not significant, in part due to the small number of years, the trend is in the right direction. However, deer censuses were not conducted in this mountainous area, and the observed reduction in the number of animals killed on the road might also be a result of a drop in deer population numbers. To assess this possibility, we used data from the Jordanelle site to inform these data.

We compared areas with and without ramps on SR 40 to shed light on the effectiveness of the ramps in reducing deer mortality (Table 3). Deer mortality increased over time in both treatment and control areas, even after the earthen escape ramps were installed. Given the general increase in traffic volume in Utah (VMT increased 60.1% from 1990 to 2001), this perhaps is not surprising. The crosswalks were still open and deer accessed the road surface. However, in the areas with the escape ramps, the increase in mortality was only about 1/3 (9.8% vs. 29.5%) that of areas that did not afford the possibility of escape. Therefore, even though deer mortality increased after the ramps were installed, the rate of increase due to increased traffic volume was much less (~66.7%) than where escape ramps were not available.

Benefits vs. Costs

Although we began our project in 1998 with the completion of the first ramps and gates, the last ramps and gates were not installed until 1999. Construction costs of both ramps and gates were calculated for 1998 and 1999. Deer use of ramps and gates were taken from the data and indicated that overall, 145 and 230 deer used the ramps in 1998 and 1999, respectively, and 14 and 32 deer used gates in 1998 and 1999, respectively. Projected gate and ramp usage was held constant at the 1999 usage numbers for the 10 year life of the project.

Results of the benefit-cost analysis indicate that net present value (NPV) is positive at all mortality levels for ramps (Table 4), but negative for gates on both SR 40 and SR 91 when mortality averted was 2% (Table 5). Ramps yielded a significantly higher NPV at all levels of mortality. For ramps, at the most conservative level of mortality avoided (2%), NPV remains positive (~$3,092) even if the project benefits and costs begin in 1998 and end in 1999.

In this study, gates were monitored for 110 (18%) fewer days than were ramps. It is therefore not surprising that ramps yielded higher benefits for the benefit-cost analysis. The seasonal nature of the ramp and gate use data we collected prevented us from legitimately calculating an average number of crossings per day for an entire year for both ramps and gates. If possible, this would have enabled a comparison of ramp vs. gate use based on year long data. Nevertheless, we were able to accurately compare the NPVs of both ramps and gates. For NPV’s of ramps and gates to be approximately equal, deer mortality avoided by ramp usage would have to be only 2% (NPV=$53,764) but deer mortality avoided by gate usage would need to be 15% (NPV=$57,948). If deer mortality avoided is 2% for gates and ramps, then a total of 213 deer (a 181% increase) would have to use the gates each year in order for the NPVs of ramps and gates to be approximately equal.

Sensitivity Analyses

Because the results of our benefit-cost analysis showed a dramatic benefit associated with ramp use, we conducted a sensitivity analysis to determine what would happen to NPV if our conservative estimates of deer value and ramp cost turned out to be too liberal. All sensitivity analyses took place using the most conservative DVC level (2% of deer are not involved in a DVC as a result of ramp usage). If deer are not valued at all ($0) and only vehicle damages are included in the analysis, NPV is positive ($1,493) at the end of the second year of the project (1999) and remains positive for the entire project life (NPV = $44,582). Further, if deer are valued at $0, we asked how much would ramps have to cost in order for 10-year project costs to just equal the benefits and learned that ramps could cost as much as $3,300 each and NPV would still be positive ($99). Lastly, we calculated how few deer would have to be saved each year of the project in order for NPV to remain positive. If deer remain valued at $0 and ramps cost $500 each to install plus $25 each for annual maintenance, as few as 48 deer per year would have to use the ramps (2% mortality = 1 deer per year saved) and NPV would still be positive ($218).

DISCUSSION

It is clear that earthen road right-of-way escape ramps are more effective than the standard steel escape gates used for decades by U.S. Departments of Transportation. Behaviorally, deer negotiate rugged terrain and appear to have little difficulty in using the ramps. When we observed mule deer attempting to traverse steel gates, we documented hesitation and false starts before the animal passed through the gate. Squeezing through the closely spaced tines of the steel gate does not appear to be done readily, although we did document a higher number of deer using the gates over time. No doubt some learning occurs. It is apparent that when placed appropriately along ROWs that are frequented by deer, elk, or moose, escape ramps can provide a very cost-efficient alternative to one-way escape gates. This analysis did not determine which, of all alternatives available to reduce the total costs of DVCs, is the most-cost efficient, nor did we determine whether the placement of the gates was the most efficient placement possible. Nevertheless, because NPV remained positive at all levels of mortality, when deer have no value, when escape ramps are very expensive, and when very few deer make use of the ramps, suggests that escape ramps provide significant net benefits and can be applied to a variety of situations.

Finally, the typical ramp-fence alignment, even though effective, may not be the most effective alignment possible (Fig. 4A). Our observations and those of R. Schultz (UDWR Conservation Biologist) in Sardine Canyon suggest that in some places different ramp-fence alignment might be more effective. For example, the alignments shown in Fig. 4 B and C take into consideration deer propensity to move parallel and close to fence lines. Movement close to the fence may be exacerbated when traffic volume is heavy and road noise is loud. Although these alignments have not to our knowledge been constructed or tested, they would seem to be the next logical step in allowing large ungulates to exit the ROW after having accessed it.

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Table 1. Number of earthen ramps and steel escape gates monitored in two locations near Jordanelle Reservoir (Summit county) and Sardine Canyon (Box Elder county), Utah 1998-1999.

	JORDANELLE		SARDINE	
DATE	JUNE – OCT 1998	MAY – OCT 1999	JUNE – OCT 1998	MAY-OCT 1999
# RAMPS	3	7	9	9
#GATES	4	8	8	8

Table 2. Comparison of use of earthen escape ramps and one-way escape gates on SR 91 (Box Elder county) and SR 40 (Summit county) Utah.

	RAMPS						**GATES**					
	SR 91			SR 40			SR 91			SR 40		
	n[a]	Days	Cross	n	Days	Cross	n	Days	Cross	n	Days	Cross
1998	9	167	101	3	88	44	10	152	8	4	83	6
INDEX	0.67			1.67			0.05			0.18		
1999	9	212	82	7	155	148	10	155	7	8	122	25
INDEX	0.43			1.65			0.05			0.26		
MEAN[2]	1.11						0.13					
RAMP/GATE RATIO[3] = ~ 8.2												

[1] # of ramps or gates, # days in observation period, # of ramp or gate crossings; [2]overall mean index value calculated separately for ramps and gates; [3]1.11/0.13 = ~8.2

Table 3. Number of deer mortalities[1] before and after the installation of Right-of-Way earthen escape ramps on State Route 40, Summit county Utah

	TREATMENT[2] MP 4-8	CONTROL[3] MP 9-13.3	END OF FENCE[4]	
			MP 2-4	MP 13-15
"BEFORE" 1992-1997	61	61	16	11
"AFTER" 1998-2003	67	79	21	14
% INCREASE	+9.8%	+29.5%	31.5%	27.2%

[1]Data from Utah Department of Transportation, [2]Treatment included fencing and ROW , earthen escape ramps , [3]Controls were fenced roads but without ROW escape ramps, [4]mortalities within 2 mile markers from the end of the fenced study area

Table 4. Benefit-cost analysis of ramp and gate use on State Route 40 in Summit county and State Route 91 in Box Elder County Utah, 1998 and 1999, extrapolated for 10 years.

	Ramps			Gates		
	Potential Mortality Level			Potential Mortality Level		
	2%	7%	15%	2%	7%	15%
Total # deer not killed	49	171	367	7	23	50
Total Benefits[1]	$65,038	$227631	$487,781	$8,859	$31,006	$66,441
Total ramp/gate cost	$11,274	$11,274	$11,274	$8,493	$8,493	$8,493
Net Present Value	$53,764	$216,357	$476,507	$366	$22,513	$57,948

[1] costs averted

Table 5. Net present value analysis of ramp vs. gates on two Utah roads over 10 years.

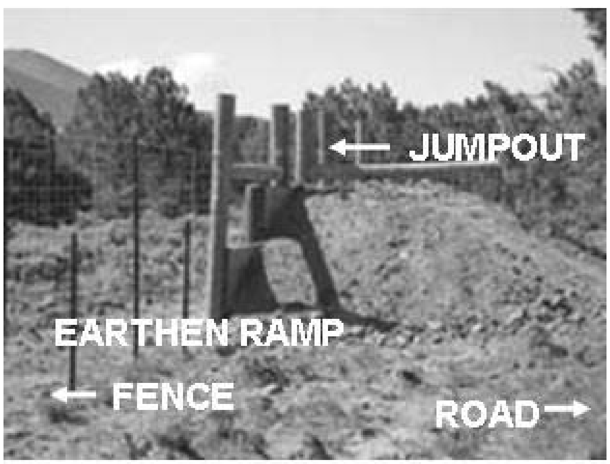
RAMPS						**GATES**					
SR 91			**SR 40**			**SR 91**			**SR 40**		
2%	7%	15%		2%	7%	2%	7%	15%	2%	7%	15%
15,647	82,952	190,636	15,877	83,718	192,281	-6,287	-771	8,055	-323	20,103	52,784

Fig. 1. Examples of an earthen escape ramp (left) and a one-way steel escape gate (right), both located on highways in Utah.

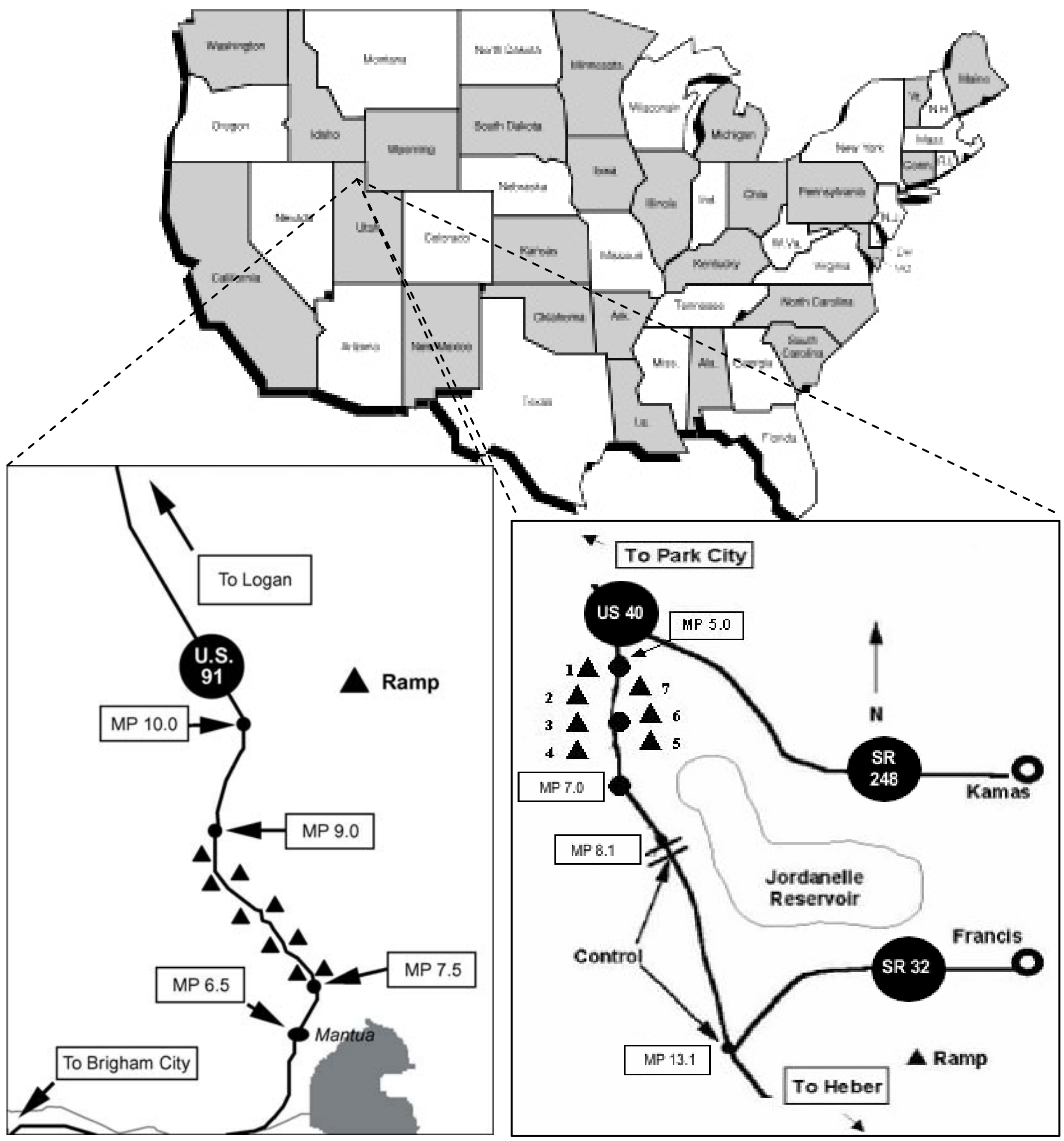
Fig. 2. Location of earthen escape ramps installed in 1997 on SR 40 near the Jordanelle Reservoir (A) and on SR 91 in Sardine Canyon (B).

Fig. 3. Deer road kill data from Sardine Canyon, Box Elder County, UT from before and after construction of earthen right-of-way escape ramps.

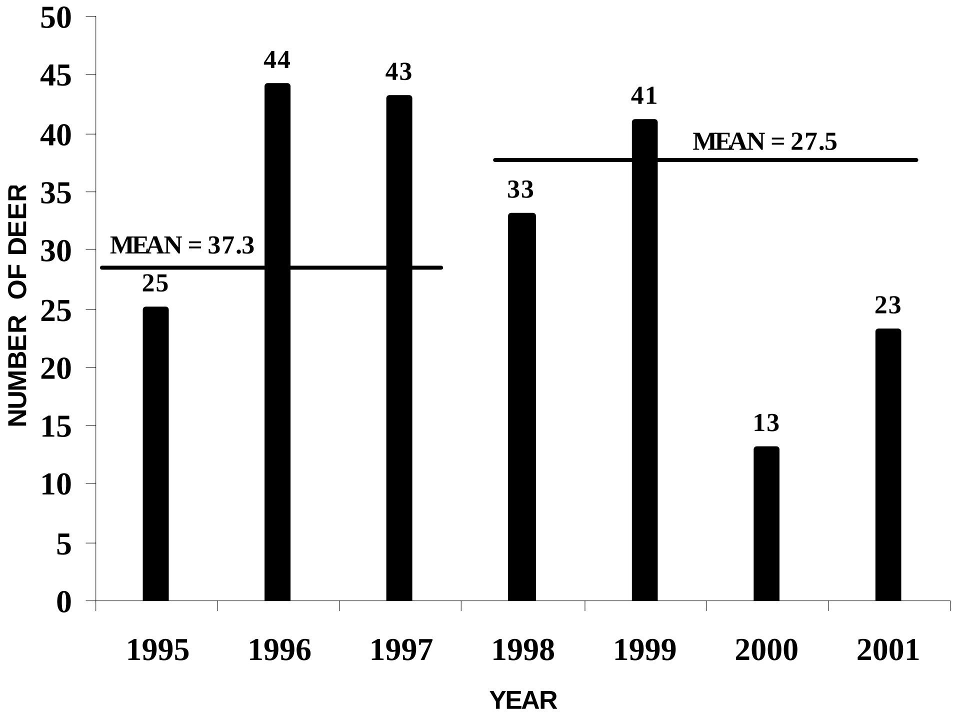
Fig. 4. The typical ramp-fence alignment (A), and useful alternate alignments (B,C)

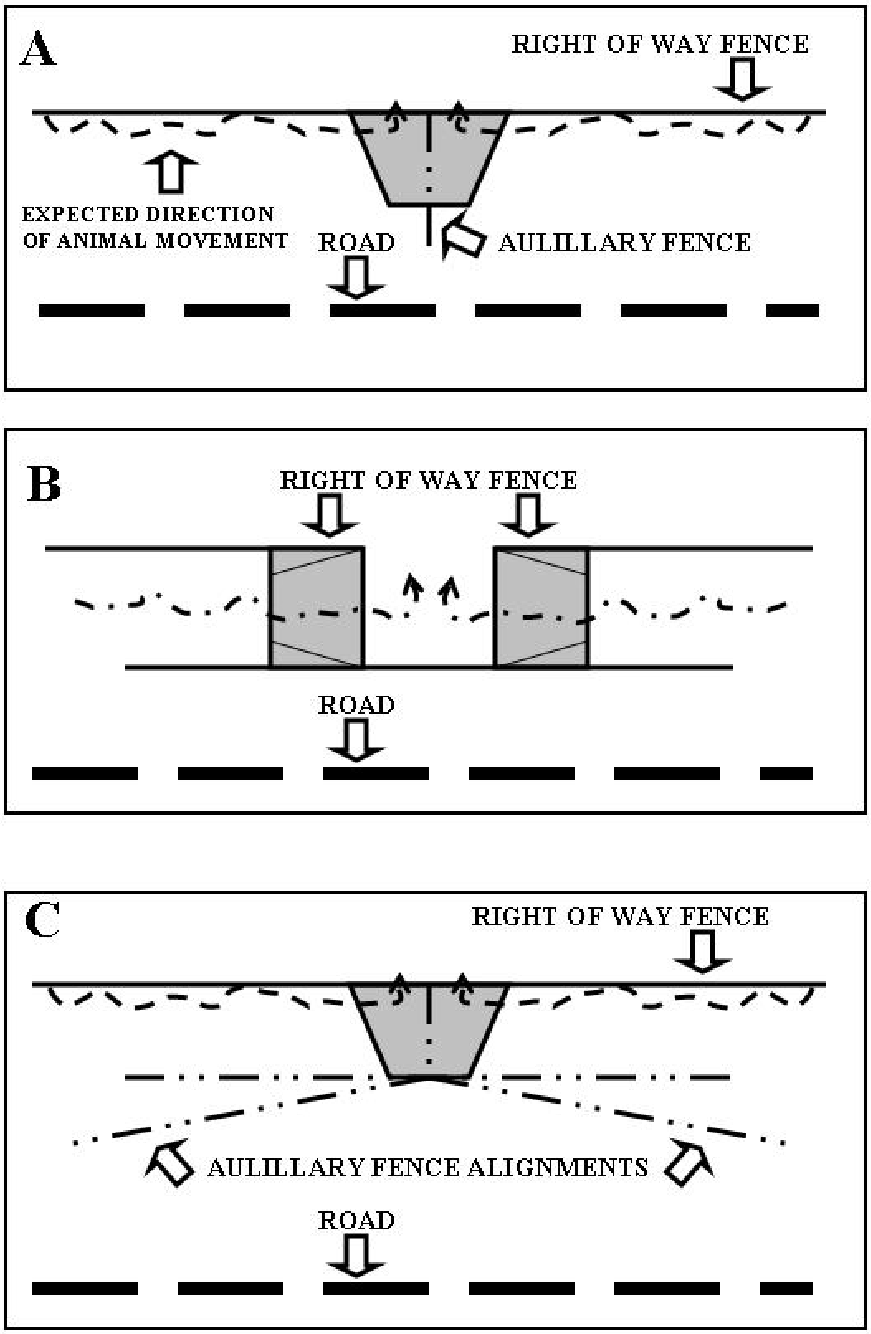

JUMPOUT
EARTHEN RAMP
FENCE
ROAD


FENCE
STEEL GATE
ROAD



To Logan
U.S. 91
Ramp
MP 10.0
MP 9.0
MP 7.5
MP 6.5
Mantua
To Brigham City
To Park City
US 40
MP 5.0
N
SR 248
Kamas
MP 7.0
MP 8.1
Jordanelle Reservoir
Control
Francis
SR 32
MP 13.1
Ramp
To Heber


50
45
40
35
30
25
20
15
10
5
0
NUMBER OF DEER
44
43
41
MEAN = 27.5
33
MEAN = 37.3
25
23
13
1995
1996
1997
1998
1999
2000
2001
YEAR


A
RIGHT OF WAY FENCE
EXPECTED DIRECTION
OF ANIMAL MOVEMENT
ROAD
AULILLARY FENCE
B
RIGHT OF WAY FENCE
ROAD
C
RIGHT OF WAY FENCE
AULILLARY FENCE ALIGNMENTS
ROAD