WILDLIFE ESCAPE MEASURES

Though fencing intended to preclude wildlife at-grade highway crossings has been beneficial in reducing wildlife-vehicle collisions and promoting permeability (Dodd et al. 2007, 2009), there is the possibility that animals can breech the fenced corridor (Forman et al 2003). In the event that animals do breach and become trapped within the fenced portion of a highway corridor, they may cause collisions with vehicles. To address this situation, a wide variety of measures to allow animals to escape from the fenced corridor may be installed. Each measure has its strong and weak points and may be suited to a given project application (Table 1). The wildlife escape measures that have been applied in Arizona, primarily for large ungulate species (e.g., elk, deer, and bighorn sheep) include:

- One-way gates (See Detail A)
- Escape ramps
  - Large wood plank ramps
    - In-line application (See Detail B)
    - Corner application (See Detail C)
  - Large concrete wall ramp (See Detail D)
  - Small escape ramps (See Detail E)
- Slope jumps (See Detail F)

ESCAPE MEASURE DESCRIPTIONS

One-Way Gates

The earliest reported application of escape measures were one-way gates (See Detail A) with spring loaded metal tines (Reed et al. 1974). Such one-way gates have been widely applied in the western U. S. and Canada, including along State Route 260. Gates are typically installed in the fence at fence offsets so that animals that travel along the fence encounter and thus pass through them to “daylight.” However, Hammer (2001) and Bissonette and Hammer (2000) reported that mule deer in Utah used earthen escape jumps 8 to 11 times more frequently than one-way gates. Dodd et al. (2007) also recorded minimal use of one-way gates along State Route 260. And though earthen jumps are considerably more expensive than one-way gates, Hammer (2001) found that they were considerably more cost effective than gates when the reduced incidence of wildlife-vehicle collisions associated with fenced corridors with ramps were considered. As such, one-way gates should be considered as a lower priority option for promoting wildlife escape from fenced corridors even with their relatively low cost and ease of installation.

Large Escape Ramps

The most effective but costly measure to allow animals to escape fenced highway corridors are large engineered escape ramps (Dodd et al. 2007, Gagnon et al. 2009); these ramps have been constructed with raised retaining walls of either pressure-treated planks (See Detail B and Detail C; Figure 1) or concrete walls on footers (See Detail D; Figure 2). In Arizona, the first escape ramps implemented along State Route 260 were very large and expensive to construct (e.g., ≥ $40,000 each). Unfortunately, their high cost has the potential to limit their application under limited budgets. Ramps are typically built on relatively level terrain with a wall erected up to 6 feet, behind which fill is used to create a sloping ramp on the fenced corridor side of the fence. An opening in the fence allows animals to jump out and down off the ramp, yet prevents them from jumping up and breeching the corridor. Perpendicular wing fences help facilitate animals slowing down and seeing the opening in the fence through which they can escape the fenced corridor. Escape ramps can be constructed in both in-line (See Detail B) and corner (See Detail C) configurations; both proved effective along State Route 260 in allowing elk and deer to escape the fenced corridor.

Figure 1. Full-sized in-line wildlife escape ramp with wooden retaining wall constructed on State Route 260. Note the landing pad onto which animals jump off the ramp on the left photo.

Small Escape Ramps

On the State Route 260 Preacher Canyon enhancement project (Gagnon et al. 2009), one of two planned engineered escape ramps was scaled back in size to make it fit into existing terrain; this scaling back also resulted in substantially lower cost while actually enhancing its anticipated effectiveness. Also, the contractor on the State Route 260 enhancement project constructed an "experimental" escape ramp (Figure 3) very similar to those used in Utah (Hammer 2001);

Colorado subsequently used numerous ramps of this design in a corridor fencing project along I-70 (NOTE: no engineered plans for this ramp design exist). These examples underscore the fact

Figure 2. Full-sized in-line wildlife escape ramp with concrete retaining wall constructed on State Route 260. Note the unsuitable rocky substrate at the landing pad below the ramp.

that smaller, scaled-down ramps that approximate the size of those widely used elsewhere in the western U.S. are both functionally and cost effective, and thus increase their application under limited budgets. A new escape ramp design constructed from anchored gabion baskets and was used along State Route 68 for desert bighorn sheep (Bristow and Crabb 2007); this escape ramp design (See Detail E) provides yet another cost-effective alternative to expensive full-sized ramp designs. Due to their lower cost and increased potential for application, along with their demonstrated effectiveness elsewhere (e.g., Hammer 2001), these small escape ramp designs provide a viable and preferred option to larger, more costly ramp designs.

Figure 3. Scaled-down ramp constructed along the Preacher Canyon section of State Route 260; the retaining wall for this ramp was constructed from recycled plastic planks.

Slope Jumps

Slope jumps are relatively inexpensive measures to allow animal escape from the fenced corridor. They require specific site conditions where an 8−12 foot section of fence is lowered to 4−5 feet (Figure 4), with the terrain sloping downward from inside the fenced corridor. Animals encountering the lowered section, which creates a visual opening, can jump over the fence onto the downhill slope. However, animals encountering the lowered section from the outside cannot jump uphill and over the section. Slope jump effectiveness is predicated upon the concept of barrier height as a function of increasing slope, as described by Payne (1994), where functional fence barrier height increased with slope steepness:

Fence height	Slope (%)	Barrier height
42”	0	42”
42”	10%	49”
42”	30%	62”
42”	40%	68”

Proper placement of slope jumps is important to their success in allowing animals trapped in the fenced corridor to escape (Gagnon et al. 2009). Slope jumps are particularly appropriate in fencing retrofit applications. An approximately 8-foot long wing fence or large rocks/boulders erected perpendicular to the section aid in slowing animals when approaching the slope jump, as animals typically travel along fence lines (See Detail F).

Figure 4. Wildlife slope jump located along State Route 260, where animals jump from over the lowered section of fence to escape from the fenced corridor (uphill side). The slope deters animals from jumping over the fence and breeching the fenced corridor.

Retrofit Bridge Abutment and Box Culvert Escape Jumps

In retrofit fencing applications (e.g., I-17 wildlife fencing enhancement project), escape jumps can be created with minimal construction effort by utilizing existing bridge abutments or box culvert headwalls (Figure 5). Were abutments and headwalls are conducive to modification with fencing to retrofit them to function as wildlife escape jumps, this can present a cost-effective alternative to engineered escape ramps. Some filling and soil stabilization may be necessary to create effective jumps at these sites. The biggest potential limitations to this approach are having sufficient abutment or headwall length to function as jumps, as well is the proximity of the abutments and headwalls to the roadway edge. Structures located too close to the roadway to may not be suited for escape jumps.

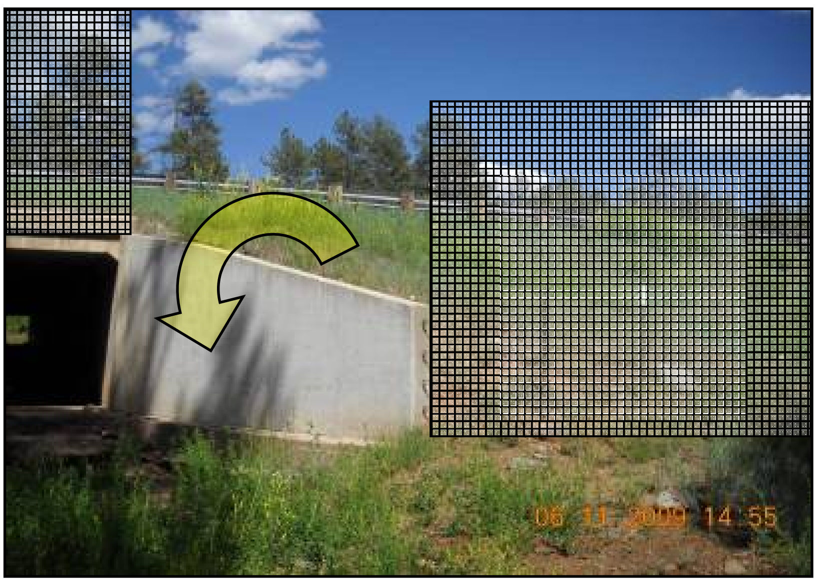
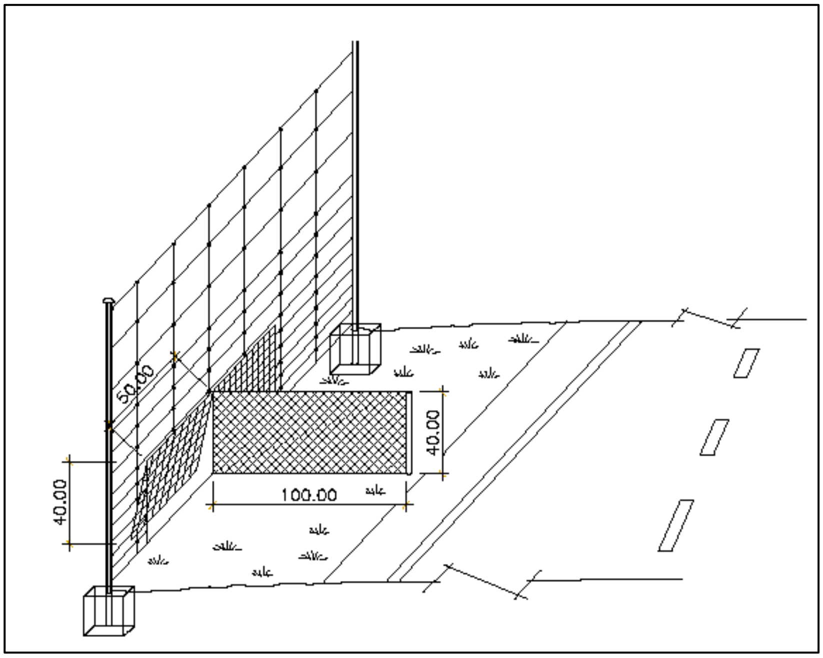


Figure 5. Box culvert headwall that is conducive to being retrofit to function as an escape jump, with raised fencing being erected on each side of the headwall, allowing animals to jump off the top of the headwall to escape the fenced corridor.

Escape Measures for Smaller Wildlife

Though most applications of escape measures have been focused on larger animals, particularly ungulates due to potential highway safety issues, there may be occasions where escape measures are appropriate for smaller animals (e.g., tortoise, fox, badgers, etc.) that may not readily jump off of ramps. Where fencing applications are intended to limit at-grade crossings by such species and/or funnel animals toward passage structures, escape measures may be needed. To date, there have been limited applications of such escape measures in Arizona. Figure 6 shows a hinged door escape measure intended for badgers in Spain; such an application could be modified with



Plexiglas panels in place of wire mesh to enhance visibility for trapped animals.

Figure 6. Escape measure designed for small species with hinged doors for escape, and with a perpendicular fence panel to slow and guide animals to and through the gates. Design was intended for badgers in Spain.

ESCAPE MEASURE IMPLEMENTATION CONSIDERATIONS

A variety of considerations in escape measure placement, height, and construction must be made to ensure successful use by targeted wildlife species. Failure to address these considerations could render even the best designed escape measure ineffective.

Landing Pads

With wildlife escape ramps and slope jumps, the substrate where animals land after jumping is a critical yet often overlooked consideration in the effectiveness of the structure. Landing pads should be relatively flat and surfaced with material such as sand, decomposed granite, or similar substrate. Rock, cobble, and other hard surfaces should be avoided on landing pads, or sufficiently covered with suitable surface material. On State Route 260, several ideally constructed large escape ramps were rendered unusable by wildlife due to unsuitable landing pads, some in conjunction with retaining wall heights that were possibly too high (e.g., 7 feet).

Escape Jump Height

The height of escape jumps is another critical consideration in the success of these structures. If the retaining wall height is too high, animals may be resistant to jumping off the top of the jump to the landing pad below. If the height is too low, animals may jump up into the ramp and breach the fenced corridor. The general recommended height for escape ramps to accommodate elk, mule and white-tailed deer, and other species is 5.5 to 6 feet. On State Route 260, numerous instances of elk jumping up onto ramps were recorded on videotape; the primary ramp where most breaches occurred was 5.5 feet high. Two simple steps can help mitigate the breaching of shorter escape ramps. First, an excavated "moat" can be dug out at the base of the ramp outward approximately 5 to 6 feet to increase the effective height near the ramp, while actually enhancing the landing pad where animals often land when they jump outward from the ramp. Secondly, a 2 to 3 foot high berm of fill can be created approximately 8 feet back from the edge of the ramp opening to limit animal visibility up onto and beyond the jump; this will effectively reduce the desire of animals to jump up onto ramps.

Spacing of Escape Measures

There are no clear guidelines for the spacing of escape measures along fenced highway corridors; spacing needs to reflect the mobility of the target species involved and the relative highway safety risk associated with potential breaching of the highway. For fencing projects involving large ungulates, it is recommended that each mile of fenced highway corridor, at least 2 escape measures be installed on each sides of the highway. This recommendation reflects a balance between promoting highway safety and cost effectiveness, with the latter addressed by the suggested application of a mix of high- (e.g., large or small escape ramps) and low-cost (e.g., slope jumps) escape measures.

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Table 1. Summary of the various wildlife escape measures available for use on highway fencing projects and their relative rating for several evaluation criterion, and an overall applicability rating.

Escape Measure	**Evaluation Criterion for Escape Measures**				
	General Effectiveness	**Relative Cost**	**Retrofit Applicability**	**Sensitivity to Proper Site Selection**	**Overall Applicability**
Large escape ramps – wood walls	High	High	Low	Moderate	Moderate
Large escape ramps – concrete walls	High	Highest	Low	Moderate	Moderate
Small escape ramps	High	Moderate	Moderate	Moderate	High
Slope jumps	Moderate	Low	High	High	High
One-way gates	Low	Moderate	High	High	Low