MANAGEMENT CONSIDERATIONS FOR DESIGNING CARNIVORE HIGHWAY CROSSINGS

Bill Ruediger
Wildlife Consulting Resources
Contracted By USDA Forest Service
Wildlife, Fish and Watershed Unit
Washington Office
December 2005

BACKGROUND: Carnivores are intelligent mammals that are usually at the top of the food chain. As such, carnivores are less abundant, less dense on the landscape, may have lower fecundity and can be more vulnerable than other terrestrial wildlife. Environmental situations such as habitat fragmentation, habitat loss and mortality often effect carnivores before other groups of animals (Ruediger 1998 and 1996). Highways have several deleterious effects on carnivores and other animals, some of these can be effectively mitigated by such measures as wildlife habitat linkage analysis and wildlife crossings. While improvements have been made in the knowledge base for wildlife crossings, much remains to be learned.

Figure 1. Lynx crossing highway. Clayton Apps photo.

For the purposes of this paper, carnivores will be loosely defined as small, mid-sized and large. Small-sized carnivores include weasel *(Mustela nivalis)*, mink (Mustela vison), skunks *(Mephitis spp),* red fox *(Vulpes vulpes),* gray fox (*Urocyon cinereoargenteus),* kit fox *(Vulpes macrotis),* swift fox *(Vulpes velox),* opossum *(Didelphis viginiana),* and American marten *(Martes americana)*. Mid-sized carnivores are arbitrarily grouped as river otter *(Lutra canadensis),* raccoon (*Procyon cancrivorus)*, bobcat *(Lynx rufus),* lynx *(Lynx canadensis)*, wolverine *(Gulo gulo)*, ocelot *(Felis pardalis),* coyote *(Canis latrans),* jaguarundi *(Felis yagouaroundi),* badger *(Taxidea taxus)* and fisher *(Martes pennanti).* Recommendations for most small and mid-sized carnivores are grouped togetherin this paper because often they are present together on the landscape, differential crossing prescriptions are not well understood and practical highway structure designs for these species would usually be similar.

Large carnivores include black bear *(Ursus americana)*, grizzly bear (*Ursus arctos*), wolf *(Canis lupus)*, mountain lion *(Felis concolor)* and jaguar *(Panthera onca).* These animals

require substantially larger wildlife crossing structures and other special considerations compared to the smaller carnivore species.

Highway coordination standards and mitigation measures are not known for many of these species. The premise of this paper is to assume highway construction and improvements will be on-going and that biologists, engineers and managers will be faced with difficult economic and environmental decisions without the luxury of understanding exactly how well some of the concepts will work. Recent history indicates that we will neither be able to delay highway projects or avoid considering various wildlife and fish ecological issues such as habitat fragmentation and mortality caused by vehicles on highways. Fortunately, we are beginning to have a number of good examples of collaborative highway mitigation measures across the United States and Canada. Specifically, those in Banff, Canada, Arizona, western Montana, Idaho, Wyoming, Colorado and elsewhere.

Carnivores are part of a much more complex natural system of animals, plants and landscapes. Biologists and engineers need to focus on the broader ecological issues when considering wildlife crossings. Often, highway safety is a prime consideration to the public, to highway departments and to political figures. It has only been recently that the issues of collisions with deer *(Odocoileus spp.)*, elk *(Crevus elaphus)*, moose *(Alces alces)* and other large animals are considered legitimate highway safety issues. Biologists will be well-served by helping highway departments deal with wildlife collision issues. Many of the wildlife crossing structures needed to address "deer crossings" work well for most large and mid-sized carnivores. If elk crossings are being considered, as they often are in the western mountains, all of the needs of large carnivore will likely be included.

Where do we begin?

When first contacted to provide a program at the Southwestern Carnivore Committee Meeting in Tucson, Arizona, it was due to a situation where some highway departments were not implementing wildlife biologist recommendations for wildlife crossings. It was requested that an expert come in to straighten the situation out – mainly the highway departments. Of course, this approach is not a winning strategy and only adds to the communication problems already in place. Wildlife crossings should be the *last* step in developing a *collaborative* wildlife habitat/transportation connectivity plan. The following is a standard approach for developing a system of effective wildlife crossings – for carnivores and other wildlife.

STEP ONE: RELATIONSHIP BUILDING

Nothing kills of good idea from maturing and being implemented like a poor relationship. This is true with wildlife concepts, road and highway plans and any other objectives humans must cooperate to accomplish. Biologists – if your wildlife crossing ideas are not being accepted, have you done the pre-work of getting to know your Forest, Regional, State DOT or FHWA engineers? Do they understand the basic ecological issues of habitat connectivity, mortality and habitat loss? Probably not. Perhaps going to local and

regional engineering meetings to present your information would help. Offer to have coffee or lunch with them. Get to know engineers you will be working with, before serious issues develop. Many engineers are not trained in ecological sciences and may need some basic information on local species, habitat fragmentation and wildlife mortality issues. Provide this information in easily-understood, clear presentations. Don't get mad or frustrated because another professional does not automatically understand issues you have taken years to develop. Biologist's need to understand that they are not the decision-makers and that a convincing, cost-efficient and effective wildlife mitigation program on a highway needs to be negotiated. If you do not have the highway mitigation coordination skills, contact biologists that has experience and credibility. Do this in consultation with the highway project manager from the State Department of Transportation (DOT).

Engineers - if your critical road project is going across public lands or sensitive wildlife habitat, invite local biologists from a variety of involved agencies to discuss what kinds of species and ecological issues might be important. Explain the transportation planning process and when your agency needs to have concerns and issues addressed so you can deliver your project on time and within the budget. Most resource agencies find the state transportation planning process confusing. Often, resource agencies such as the USDA Forest Service, US Fish and Wildlife Service, National Park Service and state wildlife agency do not expect to be involved until the NEPA alternatives are developed in the draft EIS. This may be disastrously late for project engineers to learn about serious wildlife issues and conflicts. Engineers should understand that most biologists have little or no experience in what types of structures might be effective in a situation, and that the costs of mitigation measure may not be of equal concern. Take time to explain your need to deliver a project on time and build in some costs for wildlife crossings and other ecological mitigation measures. Often biologists do their best to provide valuable wildlife coordination advice, but chances are they have never worked on a large highway project before. Highway departments should be willing to consider paying resource agencies for their biologist's time to provide quality input and coordination. All resource agencies are operating on minimal budgets and do not get money to coordinate large complex highway projects.

A critical part of the relationship building and successful wildlife crossing planning and implementation involves interagency cooperation. All successful wildlife crossings are a collaboration of: 1. State Department of Transportation and Federal Highway Administration. 2. Land management agencies and/or private landowners. 3. State wildlife management agencies and the US Fish and Wildlife Service. Often other agencies are involved such as the Environmental Protection Agency, Department of Defense etc. A common problem is that one or more of the key agencies are not involved. Land management agencies often do not look at connectivity of public lands as important wildlife habitat coordination functions. State wildlife agencies may be over-worked and view highway projects as politically charged no-win situations that they are not paid to deal with. There are almost always interagency strife and turf issues that plague most issues in government. The lead for successful interagency coordination often comes from one agency that sees the importance of coordinating highways, land management and

wildlife management. This agency may be from any of the "key agencies" and is rarely the same in any state. If your agency sees the need, take the leadership to involve and coordinate with the other agencies. Leadership, communications, problem-solving and hard work are elements common to all successful wildlife crossing efforts. Understand what your agency can contribute and come to the negotiating table willing to provide whatever resources or help that is needed.

Conservation groups and citizen committees also play key roles in many wildlife crossing and habitat linkage efforts. Several conservation groups are dedicated to helping agencies achieve successful wildlife crossings and other wildlife mitigation measures. These include Defenders of Wildlife, Southern Rockies Ecosystem Project, Rocky Mountain Elk Foundation, Wild lands Project, National Wildlife Federation, Western Wildlands and many others. These groups can provide key planning and coordination services, but can not substitute for agencies that fail to coordinate well. Many of these groups can provide for meeting coordination, local citizen participation, linkage analysis, middleman land purchases and agreements, GIS and other services.

Last, the issue of highway safety has far greater support and appeal among the general public, highway departments and politicians than conservation of large or small carnivores does. Reducing collisions with wildlife should be a concern to everyone. In many states, collisions with deer and elk are one of the most serious safety issues on rural roads. It may be prudent and effective to begin with reducing collisions with deer and elk – as all or most of these wildlife crossings will benefit carnivores. Then, if there is evidence that other crossings are needed specifically for other target species, approach these carefully, with your information and rationale well thought-out.

STEP TWO: PLANNING FOR WILDLIFE CROSSINGS – WILDLIFE HABITAT LINKAGE ANALYSIS

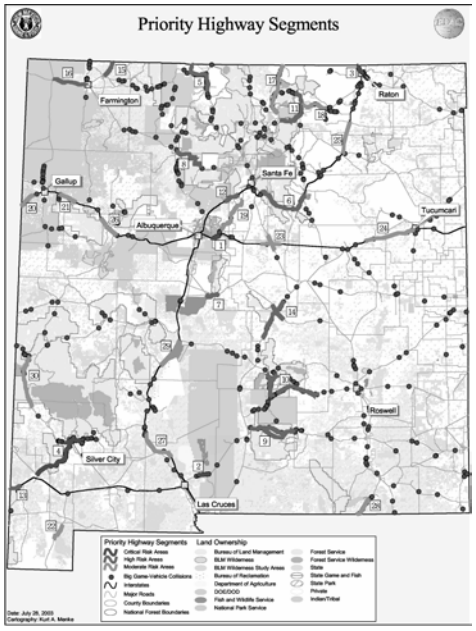

Figure 2 New Mexico Wildlife Connectivity Map

Setting up a statewide or regional plan for habitat connectivity is an essential part of developing a purposeful system of effective wildlife crossings. Most likely, the best scale to start a wildlife habitat connectivity plan is on a statewide basis, but often opportunities present themselves at smaller scales such as a DOT or Fish and Game Regional Area or on a particularly important highway. Examples of existing processes and successes include the Arizona, New Mexico, Colorado and Utah statewide wildlife habitat connectivity plans, An Assessment of Wildlife and Fish Habitat Linkages on Highway 93 – Western Montana (Ruediger et al 2004) and the Northeastern Idaho Region plan

(Servheen and Wall unpublished).

Regardless of the scale of wildlife habitat connectivity being assessed, approximately the same tools are used. These include some or all of the following:

1. **Aerial Photos:** Used in various scales and image forms such as black and white, color, color infrared, and ortho-photos. These can be used to locate vegetation patterns, vegetation types, housing and human developments, water features, aspect and terrain and many other important clues. On some high quality images such as low elevation color infrared, game trails and paths may be evident.

2. **Vegetation Maps:** Essential for all scales, although too much detail can be confusing at times. Often, general vegetation types such as conifer or hardwoods, riparian or upland, marshes or grassland will be adequate. The National Vegetation Land Class is suitable for most of the higher scale work such as statewide assessment and highway corridors.

3. **Topography Maps:** Provide important information such as draws, ridges, saddles, over-steepened lands, flats and often can be used to identify wildlife corridors. Riparian habitats are usually apparent including lakes, ponds, marshes, bogs, swamps, streams and rivers. Even on relatively flat landscapes, topography maps often provide important clues on where wildlife probably will interface with highways.

4. **Wildlife Habitat or Range Maps:** These may range in quality from "unavailable" to exceptionally accurate. They can always be augmented with information provided by biologists, foresters, landowners and others that live or work in the area. In every situation the author has worked on wildlife habitat and range information came from a variety of agency sources. These include state wildlife agencies, state heritage programs, US Fish and Wildlife Service and a variety of land management agencies such as the USDA Forest Service, Bureau of Land Management, National Park Service and State Departments of Natural Resource's.

5. **Road-Kill Information:** Available from many State DOT's. Provides valuable information on the location and number of collisions, and usually the species of animals.

Once the basic natural resource information is gathered, it is most easily stored and viewed in Geographic Information Systems (GIS). GIS data can be projected onto screens or walls for interactive sessions of large or small groups. It is essential that the land management, wildlife management and highway agency personnel be involved in selecting and prioritizing wildlife habitat linkages. Key citizens, conservation groups and others may also be critical. History indicates that if key agencies are not included, or choose not to be involved, that the habitat connectivity plans rarely result in on-the-ground wildlife crossings. Getting these agencies and citizens together for a day or two to

work collaboratively on wildlife habitat linkages and connectivity plans is often the most challenging aspect of setting in place the commitments necessary to build wildlife crossings.

State highway agency participation is particularly critical and should be included in the identification and prioritization of every wildlife linkage area. In most situations, if highway agency personnel are involved in the wildlife habitat linkage decisions and understand why an area is being identified, that other agencies support these areas and that the rationale for inclusion is solid, minimal problems occur during implementation of wildlife crossings.

Once Statewide, Regional or Highway Corridor Plans are developed, it is important that all agencies go back to their decision-makers and ensure that agency support follows. For agencies like the US Forest Service, Bureau of Land Management and National Park Service, wildlife habitat linkages need to be integrated into land management plans so that surrounding lands are managed to support wildlife connectivity objectives. For State and Federal wildlife agencies, their line officers need to be supportive if future problems develop and to avoid issues like difficult Section 7 Consultations. For state highway agencies, Wildlife Linkage Plans need to be integrated into the Statewide Transportation Plans (STIP's) as soon as possible so this information is used in developing highway construction plans and programs.

Wildlife habitat linkages are often identified at workshops using the resource information above, plus knowledge from local biologists and others. The linkages are usually documented on GIS maps and key information recorded for future use. NOTE: The information to be gathered and the forms and processes to be used should be well thought out prior to the meetings. The recording processes vary, but often include computer stored forms that include:

1. Name and number of the wildlife habitat linkage.
2. Location map and description, including the best available boundaries.
3. The species of concern for connectivity and reduction in mortality.
4. Local people from agencies and groups that have knowledge or concern about the linkage area. This includes contact information such as phone numbers, e-mails and addresses so DOT's can easily reach the right people if construction plans are proposed.
5. The major purpose or purposes for the linkage zone. This might include highway safety, migratory big game herds, rare or listed carnivores, habitat connectivity, etc.
6. The priority of the linkage area compared to all others in the state or Region. This is often described as very high, high, or moderate. Part of the priority ranking may hinge on how imminent a proposed project may be, the number of animals killed or accidents, the status of a species, or loss of connectivity due to imminent human developments.

The last step in planning wildlife linkages is documenting the results of the interagency meetings and obtaining buy-off from the DOT and other agencies. If the workshops and reports are professional and complete, this is normally not a problem. A well designed and edited Wildlife Habitat Linkage Plan does much to market the ideas and gives agency decision-makers confidence that appropriate thought and coordination has gone into the planning. Give everyone credit that was involved, regardless of the amount of effort.

STEP THREE: SELECTING APPROPRIATE WILDLIFE CROSSINGS FOR CARNIVORES

So, now you have an integrated Statewide or Regional Wildlife Habitat Linkage Plan. Your ducks are lined up and you have agency support to build wildlife crossings. One of the concerns is carnivores. What do you have to do assure use and effectiveness of the structures?

First, you need to identify the target species of carnivores involved. Are they large or small? Large would include the bears, large cats and wolves. Small and mid-sized would be the other carnivores. Ocelot, wolverine and lynx will require special consideration because of their status or rarity.

The following are suggested factors to consider when building wildlife crossings for carnivores and other wildlife species:

1. **KEEP IT NATURAL:** The more naturally a wildlife crossing fits into the surrounding area, the more likely animals will use it. Particularly for wary species like several of the carnivores like grizzly bears and wolves. Video footage from the United States and Europe indicates a wide array of behavioral responses to wildlife crossings. When wildlife crossings are unnatural appearing to animals they will approach the crossing and watch it, sometimes for several hours. After watching the crossing, some animals will cross, some will not, some will run through and some will run or walk partway through and return without making a successful crossing. It may cost slightly more money to make a crossing appear more natural, but this is usually money well spent.

   A natural appearance would be vegetation extending to the crossing structure that is similar to that in adjacent habitat. It would also include a minimal amount of features that either would intimidate or obstruct wildlife such as livestock fencing, cement walkways, rip-rap, construction debris, unnecessary fill, signing, poles, or fencing that is over-confining.

2. **LOCATION:** Location is one of the critical factors in use of wildlife crossings. In most situations, exact placement is required. Wildlife crossings should be located precisely where animals want to approach a highway, or where they have historically done so. Often, animals choose areas to cross where there is a specific terrain feature, vegetation, or a reduction in the number of lanes. Ridges, valley bottoms, stream and river courses, and wooded corridors often are choice

locations. The general location of wildlife crossings can be assessed from aerial photos. The precise location of each structure should be made after considerable field work has been done to determine the best location.

3. **APPROACHES:** How an animal approaches a wildlife crossing may be the deciding factor in whether or not wildlife use a structure. Approaches start with having a structure in the specific place where animals behaviorally are most comfortable crossing a highway. They also include habitat factors like having vegetation near or at the crossing entrance. Several animals have shown preferences for using a location where the distance between cover is the shortest. Wolverine in Canada have moved long distances parallel to highways to find such "pinch" areas. When rights-of-way are cleared for highways, vegetation should be left at those locations where wildlife crossings are planned. Trees and shrubs should be planted in approaches and between lanes for divided highways.

   Vegetation provides many benefits for a wildlife crossing. It minimizes the distance animals must travel between habitats on both sides of the highway. It shields animals from light and noise. Obviously, it provides cover which is often important to animals that are sensing vulnerability.

   Fencing is another important factor in the approach areas. This includes both fencing that funnels animals into wildlife crossing structures and fencing that often crosses the approach to keep livestock in specific pastures. Often, 5-wire barb wire fencing is used to exclude livestock from using the crossing structures. Unfortunately, such fencing also may excluding or discouraging wildlife from using the crossing. Livestock fencing should be of 3-wire design with minimal use of barb wire. The bottom wire should be high enough (normally 16 to 18 inches) to allow young animals to travel under the fence.

   Other discord elements in the approach area often reduce a wildlife crossing's effectiveness. Sediment fences are often left making use by many species difficult or impossible. Trash may be left that spooks wildlife like bright pieces of metal, boxes or other construction material. Farmers or ranchers may want to store equipment, hay, or other unnatural material in or near wildlife crossings or approaches. These should be prevented by contract agreement. Rip-rap is difficult for many species to traverse, ungulates and amphibians specifically. Also, excess fill may be placed in wildlife crossing approaches, making them more narrow and less appealing than otherwise.

   An animal should be able to see through a structure to habitat on the opposite side of the road. Road-cuts, steep drop-offs and cliffs may dissuade animals from making a successful crossing. Structures should be designed as flat and straight as terrain permits. Crossings with a steep grade reduce the "openness" of structures and dog-legs prevent animals from seeing habitat on the opposite side of the highway.

4. **BOTTOM MATERIALS AND DESIGN:** One of the hardest design features of a wildlife crossing to achieve is a suitable bottom material. As near as possible, the bottom of structures should have similar soil as would occur if the structure was not there. Often, bottom material is made up of coarse material from road cuts, or other unnatural things such as cement. For many species, bottom material may not matter. Specifically, those species that are most adaptable like coyote, black bear, raccoon, opossum

   In situations with stream and wildlife crossings using the same structure, it is usually preferable to allow a natural stream bank and let wildlife choose where to make trails or cross within a structure. Elaborate pathways are likely unnecessary and add cost. Hardened vertical walls on structures, such as those made of building blocks and cement, seem to be less desirable than those of natural fill material (soil or loose gravel). Avoidance of such designs has come mostly from ungulates and may not apply to carnivores. Likewise, avoidance or fear of vertical walls made fade after animals adapt over time.

5. **STRUCTURE DESIGN AND SIZE:** Is another "essential element" for wildlife crossing structures. Size and design affect more than biological factors, such as cost. A 4x7 meter steel multi-plate underpass structure may cost $250,000.

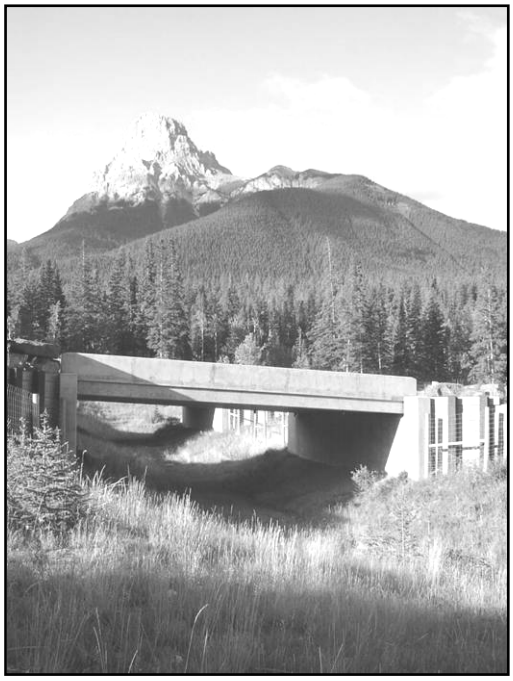

Figure 3. Open-span wildlife crossings, like this structure near Canmore, Canada are effective for large carnivores and other wildlife. Photo by Tony Clevenger.

Open-span cement wildlife crossings can cost $1.2 million, or more. And, a highway overpass wildlife crossing can easily cost $2 to $5 million. So, size and type of structure *will matter* to a highway engineer. Small increases in structure size or what may seem like subtle changes in design may have large differences in costs. All other things being equal, biologists should recommend the most cost efficient design that will work for the target species.

Carnivores are not all equal in respect to acceptance of wildlife crossings. For example, the least expensive steel multi-plate 4x7 meter crossing will likely be acceptable for black bear, cougar and most other common carnivores. However, if grizzly bear or Rocky Mountain wolves are present, open-span wildlife crossing may be more effective. In Banff National Park, the consensus of engineers and

biologists is that the best overall design, based on a number of ungulate and carnivore species, is the open-span underpass. In Florida, both Florida panther and black bear use 8'x 25' open box culverts.

As mentioned earlier, grizzly bear and wolves seem to be the most sensitive carnivore species with respect to wildlife crossing designs. Wolves in Banff National Park had a preference for open-span underpasses. Grizzlies prefer 52 meter overpasses and open-span underpasses. Black bears used a variety of crossing structures and including 52 meter overpasses, open-span underpasses, 4 x 7 meter oval culverts and even 3 x 2.5 meter box culverts. Cougar, like black bear, used a wide variety of structures in Banff National Park (Forman 2003).

Almost always, there are other large species such as deer or elk that will also be target species for wildlife crossings where large carnivores are of concern. For most of the large carnivores and deer, 10 foot height structures should be considered minimal. If elk are present, 12-13 foot height should be considered minimum. Twenty feet widths are recommended minimums for all large species. Reed (Watson and Klingel 2000) recommends underpasses have an openness ratio or index of at least 2.0 to be effective. Openness ratio or index of a wildlife crossing is determined by height x width divided by length. In some cases, either the height or width may need to be less than recommended. If less width or height is required, it is almost always better to have a slightly smaller wildlife crossing than to have no crossing.

For species that have little or no research available to determine wildlife crossing size, particularly if they are listed or rare, it makes sense to use caution and design the wildlife crossings for larger animals. In the cases of ocelot, wolverine and lynx, 10' x 20', or larger, structures should be used until better research is developed (Gordon 2003). These would be suitable for deer, black bear and cougar, too. If elk are present, structures of 4x7 meters (approximately 13' x 25') should be considered minimal. For jaguar, which there is no wildlife crossing data at this time, 10' x 20' structures should likely be considered minimal. This estimate is based on what cougar would likely use.

For smaller carnivores, smaller wildlife structures may suffice. For example, 36" pipes are commonly used for cross-ditching on large highways. A variety of small and mid-sized carnivores may use these. Generally speaking, species that dig holes, use burrows, or live or hunt in hollow logs or confined spaces frequently will likely accept 36" pipes or box culverts. These include American badger, raccoon, skunks, American marten, fisher, mink, weasel, foxes bobcat and coyote(Clevenger and Waldo 1999). A number of smaller mammals, reptiles and amphibians also have been documented using culverts this size, or smaller. Thirty-six inch pipes are the absolute minimum size that coyotes and bobcats will use. If these species are primary target species, 6' x 6' box culverts would be better. Cement pipes are preferable to corrugated steel, however, if steel pipes are

used a thin layer of soil or gravel should be placed in the bottom. Often, deer will be present and these structures will suffice for bobcats and coyotes.

Little is known about river otter, however, there is anecdotal information that otter may avoid narrow culverts or bridges on streams, and elect to move out of the stream course and across roadways. Suitable crossings should include a natural stream channel at all flows and an unrestricted bank for otter and other animals to use. Otter crossings have been designed in the Netherlands and elsewhere in Europe and are commonly used. Otter mortality has been reduced in the Netherlands and is considered an important conservation measure (Bekker 1998)

All highway bridges represent an opportunity to provide wildlife habitat connectivity and reduce wildlife mortality. Bridges are constantly being replaced as highways are improved or they become old and unsafe. Oregon Department of Transportation recently reviewed a large number of bridges that may have to be replaced and has assessed all of them for potential wildlife and fish crossing opportunities. Bridges that span waterways or gullies can be some of the most effective wildlife crossings available. This is because wildlife commonly follow riparian habitat or drainages and they usually already exist in places where wildlife wants to cross highways. Bridges can be designed to facilitate carnivore passage with minimal design changes. Usually, using the same criteria as dry wildlife crossings. Ten feet clearance above the high water zone for large carnivores and deer and 12-13 feet if elk are present. For smaller carnivores, at least three or four feet of clearance above the high-water zone is usually adequate.

Bridges often are high and open enough to allow enough sunlight to penetrate and allow growth of shrubs and grasses. There must be an adequate stream bank to allow use by target species. Bridge material should minimize traffic noise and light. Some bridges have been built with steel girders that bang loudly when traffic crosses. In Arizona elk crossings, this noise has been identified as extremely disturbing to elk trying to successfully cross.

While many bridges can serve as dual purpose structures, some design and construction practices can limit or eliminate wildlife use. These include livestock fencing that prevents access to the crossing by wildlife, rip-rap, sediment fences, debris and fill dumping and many other detracting things. Many bridges have these discord elements and most are not expected by biologist reviewing bridge plans. Bridge projects should be reviewed during and after construction to ensure the end results meets expectations and are attractive to target species. After final wildlife fencing and site preparation is finished it can be difficult to get heavy equipment back to a bridge site. There is almost never money available after the final product is inspected and approved to return and fix problems.

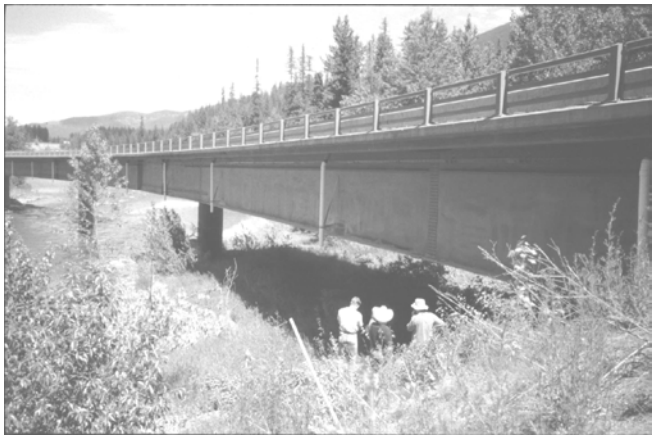

Figure 4. Bridges with adequate end-space can be excellent wildlife crossings. Bridges need to be both high and wide enough for target species.

Engineers and biologists must work hand in hand in designing and building wildlife crossings. The first attempts to build wildlife crossings often result in less than perfect structures and outcomes. As engineers and biologists learn from successes and problems, subsequent wildlife crossings often are more effective. No two situations are exactly the same and new challenges are presented at every project. If engineers and biologists have experience working with each other, problems are usually solved quickly. If engineers and biologists do not have good working relationships or are not experienced in designing and building wildlife crossings, problem situations can result in blame and taint future wildlife crossing efforts. Bringing in experts from other states or areas that have experience with wildlife crossing structures can reduce costly problems, expedite project starts and completion times and increase effectiveness. If you don't know, or are not sure what types of structures are effective, contact someone who is experienced.

6. **FENCING:** Is as critical as the wildlife crossing structures and approaches. Most wildlife is extremely wary and avoids confinement or strange situations. Given the choice between going through unfamiliar wildlife crossing structures and crossing highway pavement, many will choose the latter. Fencing forces most wildlife to use the wildlife crossings. As time goes by, research indicates wildlife species will be more comfortable using wildlife crossings. Young animals brought through wildlife crossings by their parents may readily accept crossings. It may take several years for wildlife to adapt to wildlife crossings. Without fencing, most of these animals would not use the structures (Clevenger et al 2001).

   There are usually many fencing designs. Continuous fencing such as in Banff National Park and in some parts of Florida is not feasible in most highway situation. In these cases, wing-fencing is employed. The question always arises as to how long wing-fencing must be built from the wildlife crossings. There is no simple answer. Sometimes there are natural features that funnel animals into wildlife crossings and perhaps wing-fencing can be limited to a few hundred yards on each end. Most of the time, wing-fencing should be built for ½ mile, or more, if large carnivores and deer and elk are target species. Part of the equation in how long wing-fencing should be involves the approach and wildlife crossing design. If the approach brings animals to a crossing structure naturally, and the structure itself is large enough and well designed, it is likely fencing needs will be minimal. If animals have a high resistance to using the structure, they may travel

along fences for long distances, trying to find less intimidating places to cross highways.

For large carnivores and deer and elk, 8 foot page wire is standard (Reed 1995). Bears, wolves, coyotes and other carnivores may try to dig under fences, or climb over them. There are various remedies for these problems, which are expensive and usually not needed.

NOTE: Attach fencing to bridge or crossing abutments and do not run it continuously through wildlife crossings. The fenced approach to a wildlife crossing should be as wide as possible. When fencing between lanes of a divided highway, build the fencing parallel to the highway for a short distance so it does not look like a narrow, confining shoot.

Fencing is important for small and mid-sized carnivores, too. There is less information on what works best. For most species, standard height highway fencing (4 foot page wire) will be adequate. Skunks and other small carnivores may be able to fit through 4" mesh size. In Europe, a variety of fencing material is used, including variable mesh fencing that has small-sized mesh openings at the bottom and 4"x 4" page wire on top. One half inch mesh screening is used in Europe for badger, amphibians and other small animals. Three or four foot high 2"x 4" page wire would be adequate to funnel small carnivores into 36" culverts.

7. **HIGHWAY CONFIGURATION:** Often highway configuration can be used to benefit wildlife crossings. Whereas the "openness ratio" of a 2-lane highway facilitates use of wildlife crossings by most ungulates and large carnivores, when there are 4 to 6 lanes of continuous lanes, wildlife crossings can take on the appearance of looking down a long stove pipe. By dividing highways, an intimidating wildlife crossing on a 4-lane road becomes a less intimidating set of 2-lane crossings. When highways go through improvements from 2-lanes to 4-lanes, many will have divided sections. If a vegetated corridor exists between lanes, animals can move through one side of a highway, rest or loaf, and then cross the far lanes.

STEP FOUR: WILDLIFE CROSSING FOLLOW-UP AND LEARNING FROM YOUR SUCCESSES

Much of what exists for scientific evidence for wildlife crossings and wildlife habitat connectivity is theory or anecdotal information based on biologist experience. Some of this is based on sound science principles such as large, interconnected wildlife populations being more "viable" or "persistent" than isolated small populations (Noss et al 1996; Noss 1987; Noss and Harris 1986; Noss 1983) . Reducing or minimizing mortality is important for some species, particularly those that are rare, having low

fecundity or existing in small populations. Carnivore populations often fit these situations.

Based on the high investments required to provide effective wildlife crossings, some costing over $100 million for relatively single highway projects, more scientific information is needed to guide future highway coordination with wildlife. Ideally, several states could cooperate on common wildlife crossing issues for a given species or group of species. TRB (Transportation Research Board) funds various kinds of research projects associated with transportation and could develop a comprehensive wildlife/highway research program based on specific issues or problems that need solutions. Priorities could be established and the highest priority issues would receive funding.

There is a concern among some managers and biologists that much monitoring money is being expended without rigorous scientific methodology or publication of results. Or for species or issues that have been researched repeatedly. For example, there probably is not a great deal more research that needs to be done immediately about wildlife crossings for black bear or deer. Many other wildlife species have little or no research. If the purpose of wildlife crossings and connectivity is to ensure long-term fitness of rare populations of carnivores, we have very little information on whether or not enough animals use wildlife crossings to make a difference genetically or demographically. Finding out the answers to this will not be either cheap or easy. Biologists and engineers in Europe may have answers to some of the concerns in North America. They have been building wildlife crossings for at least 40 years longer than we have, and many of their wildlife populations have greater genetic, demographic and habitat issues.

Monitoring is important on most wildlife crossing projects to see if the structures function well, or minimally. Often monitoring can result in better understanding of how to adjust existing structures to function more effectively, or how to build future structures better or more cost efficient. These results need to be shared with others in the biology and engineering fields. The efficacy of wildlife crossings is of great interest to biologists, engineers, wildlife agencies, land management agencies, politicians and the general public. Wildlife crossings and wildlife habitat connectivity measures must have credibility to avoid being labeled as “pork projects” or superfluous spending of taxpayer monies. The results of research and monitoring must include a dialog with the public, agency decision-makers and politicians. It is up to all of us to educate the public on this important work, especially the senior biologists and engineers.

LITERATURE CITED AND RECOMMENDED SOURCES:

Bekker, Hans (G.J.). 1998. Habitat fragmentation and infrastructure in the Netherlands and Europe. . In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings the International Conference on Ecology and Transportation. Pgs 151-165.

Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001. Highway mitigation fencing reduces wildlife vehicle collisions. Wildlife Society Bulletin. 29: 646-653.

Clevenger, A. P., and N. Waldo. 1999. Dry drainage culvert use and design considerations for small- and medium-sized mammal movement across a major transportation corridor. In: Proceedings of the Third International Conference on Ecology and Transportation, edited by G.L. Evink, P, Garret and D. Zeigler. FL-ER-73-99. Forida Department of Transportation, Tallahassee, FL. Pages 263-277.

Forman, R. T. T., and D. Sperling, J. A. Bissonette et al. 2003. Road Ecology: Science and Solutions. Washington D.C., Island Press.

Gordon, Kelly M. 2003. Mule deer use of underpasses in western and southwestern wyoming. In: 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garret, and K.P. McDermott. Raleigh, N.C. Center for Transportation and the Environment, North Carolina State University. Pgs 309-318.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill, and P.C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology 10(4):949-963.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environmental Management 10:299-309.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. Natural Areas Journal 7:2-13.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33:700-706.

Reed, D.F. 1995. Efficacy of methods advocated to reduce cervid-vehicle accidents: research and rationale in North America. Conference presentee lors du colloque international “Route et faune sauvage”, Strasbourg, Conseil de l'Europe, 5-7 juin 1985 and Sapporo, Japan, 27 Jan 1995.

Ruediger, Bill and John Lloyd. 2003. A rapid assessment process for determining potential wildlife, fish and plant linkages for highways. In: 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garret, and K.P. McDermott. Raleigh, N.C. Center for Transportation and the Environment, North Carolina State University. Pgs 309-318.

Ruediger, Bill. 1998. Rare carnivores and highways – moving into the 21st Century. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings the International Conference on Ecology and Transportation. Pgs 10-16.

Ruediger, Bill. 1996. The relationship between rare carnivores and highways. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation

Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.

Watson, Mark and Jon Klingel. 2000. Literature summary assessing methods for reducing deer-vehicle accidents. New Mexico Department of Fish and Game Website. http://www.wildlife.state.nm.us/conservation/habitat_handbook/Deer-VehicleAccidents.htm