Planning and Designing Effective Crossings

A Regional Ecosystem Framework for Terrestrial and Aquatic Wildlife along the I-70 Mountain Corridor, Colorado: An Eco-Logical Field Test

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ABSTRACT

Interstate 70 (I-70) is considered a major obstacle to wildlife movement in Colorado. The Colorado Department of Transportation (CDOT) has released the Final Programmatic Environmental Impact Statement, the first step in long-term planning for potential improvements to the I-70 Mountain Corridor (the Corridor) from Glenwood Springs to Denver. This planning process provides a unique opportunity to apply the Eco-Logical framework, an ecosystem based approach developed by the Federal Highway Administration to better integrate wildlife considerations and engage stakeholders in transportation planning. To accomplish this, Rocky Mountain Wild (formerly Center for Native Ecosystems) and ECO-resolutions, LLC collaborated with CDOT, Colorado Watershed Assembly and Western Transportation Institute to: 1) compile baseline information on the presence of, and use of existing crossing structures by, wildlife along I-70; 2) develop recommendations for mitigating the impacts of roads and traffic on wildlife, specifically road mortality and habitat fragmentation; and 3) facilitate the environmental review process and provide an enhanced forum for stakeholder involvement.

Original and existing information was collected relating to terrestrial and aquatic wildlife species. This information includes camera trap data on wildlife activity at existing bridges and culverts, wildlife habitat data from agencies, animal-vehicle collision data, and data obtained through a website where the public reported wildlife sightings. We then developed a transparent and repeatable process for identifying road sections that may require mitigation. This process was complemented by an extensive field survey that assessed the permeability of I-70 for select species. All information was analyzed and summarized to provide CDOT with recommendations for avoiding and minimizing impacts to terrestrial and aquatic wildlife during planning, design, construction, and operations and maintenance. In addition to site-specific recommendations, best management practices were formulated to provide general guidance for project-level planning throughout the Corridor. The recommendations were integrated into a web-based Context Sensitive Solutions Guidance Manual - a one-stop shop for project managers to identify potential conflicts with environmental and other community-valued resources.

To further support ecosystem-based planning, our team facilitated a sub-committee of agency and community stakeholders to create an Implementation Matrix to identify specific considerations for wildlife at each phase of potential infrastructure improvements. This process, based on the consensus of stakeholders, implements the goals of an interagency Memorandum of Understanding (signed by state and federal transportation, wildlife and land management agencies) to minimize impacts to wildlife.

These efforts are an excellent example of applying the Eco-Logical framework to a transportation corridor by creating a stakeholder process for incorporating ecosystem considerations. As a result, CDOT is now equipped with strategic guidance that can be used to avoid and minimize impacts to wildlife from the outset of project planning. The project will also facilitate environmental review processes by setting the stage for ongoing engagement with consulting agencies and public stakeholders and by providing clear measures and goals with which to design and evaluate transportation projects.
in the Corridor. This foundation is tantamount to the successful integration of connectivity measures into transportation projects, and can be used as a model for transportation projects across the state as well as for other DOTs.

INTRODUCTION

The Interstate 70 (I-70) Mountain Corridor (the Corridor), between Glenwood Springs and Denver, presents one of the biggest obstacles to wildlife movement in the heart of the Rocky Mountains. Studies show that an average annual daily traffic (AADT) of 10,000 creates habitat avoidance or acts as a near complete barrier for all types of species (Charry and Jones 2009) although a number of species are susceptible to road mortality or barrier effects at lower traffic volumes. A highly-traveled interstate highway, I-70 AADT counts along this 130-mile stretch of interstate range from 15,300 at the western end of the segment to 67,200 at the eastern end (CDOT 2009). From 2000 to 2035, traffic counts in one location along this already congested highway are projected to jump 55 percent on the weekends and 85 percent during the week (CDOT and FHWA 2011, ES-4). Unless appropriate mitigation measures are instituted to provide wildlife passages, the barrier effect of this roadway will be complete.

According to the Draft I-70 Programmatic Environmental Impact Statement (PEIS) released in 2005, “the primary issue affecting wildlife in the Corridor is the interference of I-70 with wildlife movement and animal-vehicle collisions (AVCs). Barriers to wildlife movement include structural, operational, and behavioral impediments to wildlife trying to cross I-70” (CDOT and FHWA 2004, 3.2-5). In the 2011 Final PEIS, CDOT states further that “[e]ven where animals can cross the highway, traffic noise and vehicle lights can deter animals from approaching the highway and animal-vehicle collisions can result in their injury or death” (CDOT and FHWA 2011, 3.2-1).

Although transportation priorities are set well in advance of construction, many biologists, conservationists, and the public only comment at the Environmental Impact Statement stage in the process. At this point, it is often too late to avoid environmental impacts since most decisions are already in place. Conservation and community needs that are addressed late in the planning process can often slow down transportation projects and become unnecessarily costly. This can result in a strained relationship between the DOT and stakeholders, as well as a less than ideal highway design from an environmental, cultural, and social perspective.

Furthermore, because highway projects are typically designed and implemented on a project-by-project basis often without a landscape scale perspective, mitigation must occur within the project boundary as opposed to the location where it is most effective. For these reasons, the current transportation planning process does not always ensure that the right conservation mitigation happens in the right place.

As the state’s population continues to grow, transportation infrastructure struggles to reduce congestion and accommodate expanding communities. I-70 in Colorado is a prime example: it is the only east-west interstate across Colorado and serves as a lifeblood of travel for Colorado and the nation, providing for the movement of people, goods, and services; it is a major corridor providing access to many of Colorado’s recreation and tourism destinations; and it is an essential link in the national interstate highway system, the principal purposes of which are to connect major metropolitan areas and industrial centers by direct routes, and to provide a dependable, interconnected highway network to serve in national emergencies.

Existing congestion along I-70 is degrading the accessibility of mountain travel for Colorado residents, tourists, and businesses. Travel demand in the Corridor is projected to continue increasing over the next 25 years and beyond. The need to relieve this congestion is especially acute for weekend travelers seeking access between the Denver metropolitan area to the central mountains and Western Slope.

To relieve congestion along the I-70 Mountain Corridor, the Colorado Department of Transportation (CDOT) initiated a planning process for I-70 and released a Draft PEIS in 2005; however, the process was highly contentious, with disagreements on the preferred alternative, environmental and social impacts, and multimodal choices. A change in leadership at both the Governor and CDOT Director levels in 2007 brought new attention to the debate. CDOT recommitted the agency to better integration of stakeholder concerns into the discussion about the future of the interstate corridor and revisited the PEIS, releasing a Revised Draft PEIS in 2010. In June of 2011, the Federal Highway Administration (FHWA) signed the Record of Decision (ROD) for the Interstate 70 PEIS.

The I-70 Eco-logical Project was developed to field test the ecosystem approach developed by the FHWA (Brown 2006). The Regional Ecosystem Framework applies an ecosystem-based approach to developing transportation infrastructure by protecting and restoring aquatic and terrestrial connectivity while also improving predictability in environmental review. The progress that CDOT has made in the long-term planning for potential improvements along the I-70
Mountain Corridor offered a unique opportunity to apply the Eco-Logical framework and find ways to preserve and restore key wildlife linkages across Colorado's high country.

The ultimate objective of the project was to develop solutions for mitigating transportation impacts on wildlife habitat connectivity along the I-70 Mountain Corridor from Golden (MP 258, west of Denver) to west of Dotsero (MP 130). To accomplish this, Rocky Mountain Wild (formerly Center for Native Ecosystems) and ECO-resolutions, LLC collaborated with CDOT, Colorado Watershed Assembly (CWA) and Western Transportation Institute (WTI) to: 1) compile baseline information on the presence of, and use of existing crossing structures by, wildlife along I-70; 2) develop recommendations for mitigating the impacts of roads and traffic on wildlife, specifically road mortality and habitat fragmentation; and 3) facilitate the environmental review process and provide an enhanced forum for stakeholder involvement. These efforts are an excellent example of applying the Regional Ecosystem Framework to a transportation corridor by creating a stakeholder process for incorporating ecosystem considerations.

BACKGROUND

A Landscape Level Inventory of Valued Ecosystem Components (ALIVE)

In 2001, CDOT and FHWA convened an interagency group of wildlife specialists called A Landscape Level Inventory of Valued Ecosystem Components (ALIVE) to consider the negative impacts of existing and proposed transportation systems on wildlife habitat and movement patterns, and to guide mitigation development strategies as a part of the I-70 PEIS (CDOT and FHWA 2004). Other agencies engaged in the ALIVE committee include those responsible for the protection and management of wildlife habitats and threatened and endangered species – the Colorado Division of Wildlife (CDOW), the Bureau of Land Management (BLM), the US Forest Service (USFS), and the U.S. Fish and Wildlife Service (USFWS). The objective of this cooperative effort was to agree up-front to conservation strategies and mitigation measures to ensure timely environmental clearances for projects prioritized under the PEIS (Solomon 2007, 3).

The main goals of the ALIVE committee were fourfold:

- Designation of key wildlife habitat including Canada lynx habitat.
- Identification and characterization of linkage interference zones [or important wildlife movement areas].
- Analysis of specific conflict areas for wildlife roadway crossing within the linkage interference zones.
- Recommendations for mitigating conflicts through wildlife crossings and other techniques including fencing and land conservation strategies. (CDOT and FHWA 2004, 3.2-6)

Considering both existing data and expert opinion on wildlife movement, the ALIVE committee identified thirteen LIZs in the I-70 Mountain Corridor between Denver and Glenwood Springs. The ALIVE committee also proposed specific recommendations, including wildlife crossings and land protection, for each zone (CDOT and FHWA 2004). In 2008, at the outset of the I-70 Eco-Logical Project, the cooperating agencies and municipalities reconvened to sign a Memorandum of Understanding (MOU) to recommit to the collaborative effort for the Revised PEIS and leverage efforts on future projects in the I-70 Mountain Corridor on behalf of terrestrial and aquatic resources (CDOT and FHWA 2011, ES-7).

Stream and Wetland Ecological Enhancement Program (SWEEP)

The CDOT convened Stream and Wetland Ecological Enhancement Program (SWEEP) committee, initiated through the I-70 PEIS process, is an inventory of water resource-related issues in the Corridor. SWEEP includes representatives from several federal, state and local government agencies, including USFWS, USFS, BLM, CDOW and Clear Creek County; various watershed associations including Clear Creek Watershed Foundation, Upper Clear Creek Watershed Association and Eagle River Watershed Council; and special interest groups such as Colorado Trout Unlimited. A MOU was signed between these groups in 2011 to coordinate and leverage efforts on future projects in the I-70 Mountain Corridor on behalf of aquatic resources. Though SWEEP focuses on a variety of issues regarding stream and wetland health, coordination between the ALIVE and SWEEP groups will ensure consideration of aquatic connectivity throughout the Corridor (CDOT and FHWA 2011).

Context Sensitive Solutions (CSS)

The I-70 Mountain Corridor Context Sensitive Solutions (CSS) process was developed by CDOT and I-70 Mountain Corridor Stakeholders “to consider the total context of a proposed action—not just the study's physical boundaries” (Peter Kozinski, CDOT, pers. comm., June 23, 2011). The CSS process is intended to guide all future and/or Tier 2 processes in the I-70 Mountain Corridor, incorporating the goals of many of the I-70 Mountain Corridor Core Values – such as sustainability, biological resources, and communities – at each stage. The web-based CSS Guidance will
provide Tier 2 project leaders and teams with the pertinent information and data available for the variety of issues, including habitat connectivity, which may occur at each future project location (CDOT and FHWA 2011).

METHODS AND RESULTS

A major outcome of the I-70 Eco-Logical Project are site-specific recommendations and general guidance for improving terrestrial and aquatic connectivity along the I-70 Mountain Corridor. An extensive field survey was conducted to assess the current permeability of I-70 for select species, and served as the foundation for developing mitigation recommendations for improving existing structures or constructing new structures to provide safe passage. In addition, original and existing information was compiled on terrestrial and aquatic wildlife; this information derived from a variety of sources including camera trap data on wildlife activity at existing bridges and culverts, wildlife habitat and species presence data from agencies, animal-vehicle collision data, and data obtained through a website where the public reported wildlife sightings. This compilation of data and information was then used to develop a transparent and repeatable process for updating and validating the 13 LIZs identified in 2003 and development an analogous process for identifying road-stream crossings that are important for aquatic connectivity. All of this information was analyzed and summarized to provide CDOT with recommendations for avoiding and minimizing impacts to terrestrial and aquatic wildlife during each of the life cycle stages of future transportation projects.

Data Compilation

Inventory of Potential Wildlife Passages and Barriers to Movement

The purpose of the roadway inventory was to characterize the stretch of interstate between MP 130 (west of Dotsero) and MP 258 (Golden) with regards to habitat connectivity for wildlife (Figure 1). This stretch of interstate crosses multiple ecological zones and extends from an elevation of 5,700’ west of Golden to over 11,000’ at the Eisenhower Tunnel, and back down to 6,100’ at Dotsero.

Figure 1. I-70 Eco-Logical Study Area, Mile Post 130 to 258.
Within the study area, every structure greater than one meter in diameter, including pipes, bridges and culverts, was inventoried and characterized according to its potential to function as a wildlife passage. Other locations without an existing structure, such as fill slopes, where wildlife are barred from crossing the roadway or attempt to cross at grade were also inventoried. At each location, site-specific data were compiled to characterize habitat connectivity across the roadway for terrestrial and, if applicable, aquatic wildlife. The inventory included structure dimensions and characteristics, habitat information, fencing and other barriers to movement. Sites identified as having an aquatic component were further assessed based on a number of additional criteria designed to evaluate connectivity for aquatic species.

In addition to the roadway inventory, a GPS unit was used to map stretches of roadway with wildlife fencing, including gaps in the fencing (for example at highway interchanges). Locations that tie into an existing structure (i.e. bridge or culvert) with no resulting gap were not mapped; nor were locations where the fencing connects into a natural barrier, such as a cliff wall, and starts up again a few tenths of a mile up the road. One-way deer gates and escape ramps have also not been mapped. Other barriers to wildlife movement within 100 meters of the roadway – such as steep cliff bands and retaining walls – were included in the inventory.

Camera Monitoring

Camera monitoring was conducted to collect baseline information on the presence and use of existing crossing structures by wildlife along I-70. In 2009, cameras were set up at 29 monitoring stations at 15 milepost locations. Over the course of the 2009 field season, this was increased to 34 stations at 19 milepost locations. In the 2010 field season, cameras were set up at 39 monitoring stations at 24 milepost locations, targeting sites preliminarily identified as important for wildlife movement. Monitoring locations included existing bridges and culverts as well as potential crossing locations – such as fill slopes blocking natural drainages – where there are no suitable crossing structures.

Monitoring activities in 2010 were focused within areas of identified connectivity concern as determined by a preliminary analysis used to validate and refine previously-identified LIZs first mapped in 2004 by the ALIVE group. Recognizing that camera monitoring does not fully capture all wildlife activity at a site (Bonaker 2008), in 2010 an attempt was made to expand monitoring to include track beds using the existing substrate at the site. However, due to insufficient substrate that did not register track imprints well, the track beds were discontinued for the purposes of this study, as they were contributing little additional data at a high cost of staff time and travel. Anecdotal data from the track beds was collected when researchers were in the field to maintain the cameras every four to six weeks. No monitoring was conducted to track measures of aquatic connectivity as a part of this study.

Camera monitoring captured activity by a variety of species across the study area. The most frequently photographed species was mule deer. Elk, red fox, black bear, rabbit/hare, raccoon and coyote were also commonly caught. Other species captured by the cameras include marmot, badger, striped skunk, squirrel, moose, gray fox, porcupine, bighorn sheep, weasel, wood rat, red-tailed hawk, bobcat and mountain lion, as well as domestic animals such as goats, cattle, dogs and house cats. Human use at monitoring stations varied from none to frequent, depending on the location. Some level of human activity was documented at nearly all of the culvert and bridge locations, while little to no use was documented at monitoring locations without structures. Very little wildlife activity was recorded at structures that received regular movement of passenger cars and trucks through the structures. One camera was stolen in 2009, three in 2010.

Terrestrial Habitat Data

Wildlife habitat data were compiled for each terrestrial target species within the I-70 Mountain Corridor for which spatial data was available. Target species included any species with threatened and endangered, sensitive, and other special status, or any other species with a safety or habitat fragmentation concern in the context of the I-70 Mountain Corridor. Data used in this analysis includes data from various sources for AVCs and habitat layers for bighorn sheep, black bear, boreal toad, elk, lynx, moose, mountain lion, mule deer, northern leopard frog, Preble’s meadow jumping mouse and river otter, which were derived from CDOW’s Natural Diversity Information Source database and other sources.

Aquatic Species Presence and Habitat Data

The aquatic target species included any threatened and endangered, sensitive, and other special status native species found in the Corridor as well as any native species presenting a barrier or habitat fragmentation concern in the context of the I-70 Mountain Corridor. The aquatic target species were vetted with aquatic biologists at CDOW and USFWS.

CDOW is the authoritative source for all aquatic data in the state of Colorado (Harry Vermillion, CDOW, pers. comm., March 10, 2011). Therefore data was requested from the agency to determine whether the presence of target species
were confirmed, absent or unknown (some structures had no available data) at each inventoried location with perennial flow. At some locations, natural or man-made barriers are desirable in order to protect existing native cutthroat trout populations from invasion by non-natives, allow for the potential to reclaim habitat for native cutthroat trout populations and/or protect current fish populations from whirling disease. Information on intentional barriers throughout the study area was obtained through communications with the individual aquatic biologists at CDOW whose assigned districts fall within the Corridor. Due to the potential to restore native cutthroat trout to some stream segments, some locations were identified as potential barrier locations even though there is currently no barrier present.

I-70 Wildlife Watch

I-70 Wildlife Watch is a web-based wildlife observation data collection tool that allows motorists to report wildlife, both alive and dead, that they see along I-70 between Golden and Glenwood Springs. The website was developed by WTI at Montana State University (MSU) for the I-70 Eco-Logical Project and was modeled after similar websites in British Columbia, Canada, Ketchum, Idaho and Bozeman Pass, Montana. This on-line database works both to educate drivers about wildlife crossing issues along I-70 as well as compile opportunistic information on wildlife activity along the highway that cannot otherwise be determined from road-kill counts or accident reports.

A number of complementary strategies have been implemented to teach the public about I-70 Wildlife Watch and encourage them to participate, beginning with a press event at the Colorado Division of Wildlife headquarters in Denver, Colorado on November 9, 2009. The website launch was conducted in coordination with the Colorado Wildlife on the Move coalition which is composed of Rocky Mountain Wild, ECO-Resolutions, LLC, CDOT, Colorado State Highway Patrol (CSP), CDOW and Rocky Mountain Insurance Information Association. Additional outreach efforts consisted of a billboard deployed at two strategic times during the study period with associated press releases, handouts such as flyers and business cards, and a Friends of I-70 Wildlife Watch concept aimed at getting other businesses and organizations to promote use of the website through various means. For instance, Denver Zoo has a link to I-70 Wildlife Watch on their conservation webpage and has promoted the website at a variety of events.

Motorists were asked to participate in I-70 Wildlife Watch by reporting wildlife observations, dead or alive, over a distance of about 145 miles - between exit 114 (West Glenwood Springs) and exit 259 (US40 - Red Rocks/Golden/Morrison). Users were required to answer several questions about their observation including: was/were the animal(s) road-killed or alive, the location of the animal(s) in relation to the roadway, species, number of individuals sighted, date and hour of the day of the sighting, which exits the driver entered and exited the roadway on the trip when the animal(s) was sighted, and how many times the observer has driven the same section of highway prior to the observation date without making an observation.

Between November 9, 2009 and April 19, 2011, users submitted 330 unique wildlife reports of live animals. Some sightings were of more than one live animal; therefore, the total unique animal count for all species was much higher at 1227 animals. The largest proportion of live observations was attributed to bighorn sheep followed by mule deer and elk. Users also submitted 100 unique reports of dead animals. The largest proportion of carcass observations was attributed to mule deer followed by unknown and red fox.

By requiring users to note where they entered and exited the highway when a sighting was made, a general sense of reporting effort can be assessed, such that patterns of observations can be discerned while controlling for the number of times that a given segment has been travelled. In general, correcting for observers seemed to accentuate the number of sightings in the western portion of the study area while it minimized the number of sightings in the east. This is due to the fact that there were fewer drivers participating in the website in the west compared to those participating in the east. Comparing the exit data to the AADT also began to tell us where people are participating and where additional outreach is needed. The largest percentage of the AADT participating in the website occurred on West Vail Pass and the smallest between the two exits for Glenwood Springs.

Observations collected by the public on I-70 Wildlife Watch complements other data on wildlife habitat and activity adjacent to the roadway. Before the website was instituted, much of the knowledge about wildlife activity near the roadway was based solely on AVC data collected by CSP and CDOT. These data consist mostly of collisions that were serious enough to report; therefore, AVCs are generally recognized as being severely underreported as well as unevenly reported over time and geographies. Romin and Bissonette (1996) recommend factoring in a 16-50 percent reporting rate when estimating AVC levels from accident reports. The sightings reported by motorists in the I-70 Mountain Corridor greatly expanded our knowledge of where live animals are most frequently seen along the roadway as well as about otherwise under- or unreported road-killed animals (i.e. smaller animals such as red fox and raccoon).
Data Analysis and Recommendations Development

Terrestrial Connectivity Locations - Linkage Interference Zones - 2011

The ALIVE committee used expert opinion to assess the best available data at the time to identify the 2004 LIZs, however the decision-making process was not rigorously systematic or repeatable, preventing future revisions using the same methodology. The I-70 Eco-Logical Project therefore developed a new approach for validating and refining the 2004 LIZs with the objective of creating a consistent and transparent process for reassessing terrestrial connectivity zones along the I-70 Mountain Corridor. These refined zones, by agreement of the ALIVE committee, are called Linkage Interference Zones 2011 (LIZs-2011), to distinguish them from the LIZs identified in the original assessment in 2004.

The primary steps for this GIS supported analysis included identifying primary and secondary parameters for prioritizing road segments based on their potential contribution to habitat connectivity for wildlife; ranking and tallying the presence/absence of these primary parameters for each 1/10th mile segment along the Corridor; and applying decision rules for delineating discrete connectivity zones within each bioregion and applying the secondary criteria as appropriate. An objective for the analysis was to identify at least one LIZ-2011 within each bioregion of the study area.

The primary parameters mentioned in the data compilation section above (i.e., target species or AVC data), were ranked on a standardized scale so that all values at a given location could be summed. Each parameter was given a maximum score to avoid one parameter having an unreasonable weight within an analysis segment. This also helped maintain a balance between parameters that have more or less sub-parameters, or available habitat and movement data layers. Federal and state threatened and endangered species were given a higher maximum possible score than the more common game species.

Available data layers for a given focal species were included in the analysis only if the habitat was identified as important habitat (e.g., winter range, movement corridor) for that species. In general, CDOW rankings (2008) for priority wildlife habitat for economic species and species at risk were used as a guideline for prioritizing and scoring sub-parameters. In determining scores for each sub-parameter, species identified as ‘sensitive’ (e.g., boreal toad and Canada lynx) and more sensitive habitat types (e.g. boreal toad breeding sites) were given a higher individual score than more general habitat types (e.g. overall range), unless the CDOW rankings (2008) used for guidance dictated otherwise.

In the GIS, these habitat values were related to a buffered layer of I-70 reflecting the boundaries of our study area, divided into 1/10th mile segments. Total scores were calculated for each 1/10th mile segment and smoothed with the adjacent scores to acknowledge that one segment is likely influenced by its two neighboring segments (Huijser et al. 2008, 21). Based on the smoothed scores, the 20th, 40th, 60th, 80th and 100th percentiles were calculated. A series of decision rules and secondary criteria were applied to the ranked 1/10th mile segments to delineate the final 2011 LIZs. This analysis process and results went through a thorough review process by the ALIVE committee, including several in-person meetings, to ensure acceptance of this dataset by the stakeholder groups and its inclusion in decision-making about the Corridor, specifically, to inform mitigation measures for wildlife connectivity.

Seventeen distinct connectivity zones, representing five of the six bioregions in the I-70 Mountain Corridor, were identified (Figure 2). The alpine bioregion, the only one not represented in the LIZ-2011s, is very short and has an existing land bridge over the interstate for most of its entirety where the Eisenhower/Johnson Tunnels cross under the Continental Divide. The primary parameters exerting the greatest influence on how each LIZ-2011 was defined and mapped include elk, mule deer, lynx and animal-vehicle collisions.

A comparison of the 2011 and 2004 LIZs shows some locations identified in both analyses as well as several that were only identified in one or the other. Seventeen LIZs, covering approximately 51 miles, were identified in the 2011 analysis, compared to 13 zones encompassing 65 miles in 2004. The 2004 analysis also included two LIZs for which sub-segments were identified. While both analyses incorporated many of the same types of data layers, the LIZ-2004 process was based on expert opinion assessing the available data layers. In addition, the specifics of the LIZ-2004 analysis process are not well documented, and so the process is not replicable with more up-to-date datasets.

Mitigation recommendations and guidelines for improving permeability for terrestrial wildlife were developed for each of the revised LIZ-2011s. Data from the camera monitoring and I-70 Wildlife Watch were used to further refine the recommendations by providing pertinent information at specific locations along the Corridor. Through the ALIVE MOU, CDOT and other participating agencies have committed to using updated data such as these during Tier 2 processes, which guide planning and design for specific infrastructure projects in the I-70 Mountain Corridor (ALIVE MOU 2008).
Aquatic Connectivity Locations

In order to make site-specific recommendations at aquatic structures within the study area, we assessed each inventoried location with perennial flow to determine whether or not it presents an aquatic connectivity concern. The two main criteria used to decide whether a location is a priority for aquatic connectivity were: 1) presence of a target species and 2) absence of intentional barriers along the stream segment.

Site specific recommendations were developed for locations determined to be a priority for aquatic connectivity because of the presence of a target species and the absence of intentional barriers. Site-specific recommendations were also made for locations with unknown connectivity priorities, or sites where the presence of a target species is unknown but no intentional barriers exist. This process was vetted with both the ALIVE and SWEEP committees.

General Terrestrial and Aquatic Guidance

In addition to site-specific recommendations, a comprehensive suite of guidelines for improving permeability for terrestrial and aquatic wildlife was developed to inform projects throughout the Corridor, regardless of whether or not they fall within an identified LIZ. This guidance was compiled from a synthesis of best management practices in use by state and federal agencies and recommended by research studies across the nation, and was reviewed by road ecology colleagues in several states. The guidance includes practices for siting and designing pipes, culverts and bridges to facilitate wildlife passage.

Stakeholder Processes

ALIVE, SWEEP and CSS Processes

The I-70 Eco-Logical Project team members have worked closely within the framework of the previously established stakeholder groups in the I-70 Mountain Corridor to communicate with and engage stakeholders in the project. Such stakeholder involvement is essential for building support among communities, partner agencies and other interest groups as transportation projects proceed through visioning, planning, design and construction. Early engagement ensures that stakeholder concerns are duly considered and incorporated into the transportation planning process and improves predictability in the environmental review process.
The project team collaborated with the ALIVE and SWEEP committees to ensure that stakeholders played a major role in defining the objectives of the project, reviewing the processes for evaluating connectivity concerns and needs, and critiquing project outcomes. This consisted of regular in-person meetings throughout the life of the project to update stakeholders on the status of the project and gain valuable feedback which was incorporated in subsequent steps. Before the I-70 Eco-Logical Project terminated, both the ALIVE and SWEEP committees agreed to hold annual meetings to address upcoming projects, thereby ensuring that stakeholder engagement continues beyond the life of the project. CDOT has further committed to providing quarterly updates to members of both committees regarding future projects big and small to ensure that stakeholder participation continues in the future.

All data and recommendations resulting from the I-70 Eco-Logical Project have been integrated into the web-based CSS Guidance Manual which is a one-stop shop for project managers to acquire data on environmental and other community-valued resources and to identify potential conflicts at the outset of transportation planning processes. The CSS Guidance Manual includes standard design solutions, historic context, and decision making procedures to be used at each life stage of project development along the Corridor. Incorporating connectivity into the CSS process ensures that the products from the I-70 Eco-Logical Project will be applied as projects move from one life stage to the next in the I-70 Mountain Corridor.

ALIVE Implementation Matrix

To further support ecosystem-based planning and coordination among agencies and stakeholders, the project team facilitated a sub-committee of agency and community stakeholders to create an Implementation Matrix to identify specific considerations for wildlife at each phase of potential infrastructure improvements. This process, based on the consensus of stakeholders, strengthens the ALIVE process by implementing the goals of the MOU to minimize impacts to wildlife throughout the I-70 Mountain Corridor. The process was modeled after a similar matrix developed by the SWEEP committee to carry out the goals of their MOU.

The ALIVE Implementation Matrix was developed by a working group that included members from CDOT, CDOW, USFS, USFWS, ECO-resolutions, LLC, Rocky Mountain Wild and Clear Creek County. After completing a draft with the working group, the Matrix was reviewed by the full ALIVE committee before the final was submitted to CDOT.

The ALIVE Implementation Matrix outlines specific inputs (e.g., wildlife and land use data), considerations (e.g., what opportunities exist to improve, protect or restore permeability and habitat components?), and outcomes (e.g., avoidance and mitigation strategies) necessary for consideration at each of the five life cycle phases for improvements in the I-70 Mountain Corridor that are needed to improve, protect, or restore permeability for wildlife and important habitat components, as put forth in the ALIVE MOU. The five life cycle phases include 1) corridor planning, 2) project development, 3) project design, 4) project construction, and 5) operations, maintenance and monitoring. As activities in the Corridor move from corridor planning to project development to project design and so on, the outcomes from the previous phase become inputs for the subsequent phase. This approach is consistent with the Life Cycle Phases and 6-Step Process in the CSS Guidance for the I-70 Mountain Corridor (CDOT 2010).

This matrix further applies the Eco-Logical framework by implementing the main objective of the ALIVE MOU which is to “increase the permeability of the I-70 Corridor to terrestrial and aquatic species....This includes development of management strategies that will result in the long-term protection and restoration of wildlife linkage areas that intersect the I-70 Corridor, improve habitat connectivity, and preserve essential ecosystem components” (ALIVE MOU 2008).

DISCUSSION AND CONCLUSION

The recent progress that CDOT has made in the long-term planning for the I-70 Mountain Corridor has presented a unique opportunity to field test the Regional Ecosystem Framework developed by FHWA in 2006. As a result of this project, CDOT is now equipped with a comprehensive assessment of permeability for wildlife throughout the I-70 Mountain Corridor as well as the tools for integrating corrective actions in future projects to improve habitat connectivity for wildlife. The establishment of a framework for integrating connectivity data and concerns as well as stakeholder review will bring both immediate and long-term benefits, helping to streamline projects and produce sustainable projects that meet ecological, community, and transportation goals.

In addition to supporting stakeholder engagement, the I-70 Eco-Logical Project resulted in the compilation of a comprehensive dataset about the state of habitat connectivity for wildlife in the Corridor, and provided detailed recommendations for improving connectivity. The seventeen identified LIzs-2011 and aquatic connectivity locations reflect our best understanding of wildlife movement needs across the interstate, and these can be easily updated as new data becomes available, for example, for species for which spatial datasets are currently lacking. While compiling
data and producing new data can be a time-consuming endeavor, such data collection efforts form the backbone of support for decision-making; by having these data on-hand, the agency no longer needs to choose between postponing project-level decisions for lack of data or making decisions based on a paucity of data.

As the I-70 wildlife data and recommendations are now integrated into the CSS website, project managers see connectivity concerns flagged each time a new project overlaps an identified LIZ, facilitating considerations of these concerns from the earliest stages of project visioning and planning. The recommendations provided offer initial guidance for restoring permeability for wildlife across the interstate. As engineering solutions expand and research helps us learn what works and what doesn’t work for different species, these preliminary recommendations can be tailored or even revised to provide the best connectivity solution at a given location.

While the CSS database and the Eco-Logical database were prepared specifically for the I-70 Mountain Corridor, they may be expanded to cover the entire state to support planning efforts across Colorado. While the stakeholder groups were convened prior to the I-70 Eco-Logical Project, they lacked a clear system for how and when to engage, such that neither CDOT nor the stakeholders themselves knew how to effectively engage. Through this field test, a clear framework has been developed for ensuring that stakeholder concerns and information are integrated at each life cycle phase in the planning process.

The I-70 Eco-Logical field test has demonstrated the value of well-defined stakeholder engagement procedures and up-front data compilation efforts to support transportation planning that considers the full landscape context – both ecological and human. By making this information fully accessible to project engineers as well as interested partners outside of CDOT, the responsibility for ecological-based decision-making extends beyond agency biologists and provides a foundation for integrative projects and sustainable transportation infrastructure.

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BIOGRAPHICAL SKETCHES

Paige Singer was the project coordinator and GIS specialist for the I-70 Eco-Logical Project. She has been a staff biologist/GIS specialist for Rocky Mountain Wild (formerly Center for Native Ecosystems) since 2008. She has a B.A. in Psychology from Stanford University, and an M.S. in Environmental Studies from the University of Montana. Paige has studied human-wildlife interaction issues in areas as diverse as Montana and Africa. Before coming to RMW, Paige coordinated the Citizen Science Wildlife Monitoring Program with the Southern Rockies Ecosystem Project.

Julia Kintsch was the project director for the I-70 Eco-Logical Project. She is a conservation ecologist and the founder of ECO-resolutions, LLC ecological resources consulting, where she conducts wildlife and habitat assessments, develops road-wildlife mitigation recommendations, and facilitates conservation management for public, private and non-profit clients. Julia holds a Master’s Degree in conservation biology from Duke University and has extensive experience in conservation planning, ecological resource management, and mitigating impacts from infrastructure and human activities on wildlife. Previous roles include conservation scientist at Freedom to Roam, director of programs at the Southern Rockies Ecosystem Project, and conservation planner at the Nature Conservancy.

Marcel P. Huijser was the terrestrial principle investigator for the I-70 Eco-Logical Project. He received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present) and he is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation.

Alison Huyett was the project assistant for the I-70 Eco-Logical Project. She was the Assistant Staff Biologist at Rocky Mountain Wild (formerly Center for Native Ecosystems) from 2009 to 2011. Her main roles for the I-70 Eco-Logical Project were field data collection, data management and analysis, and assisting with various reports. During her time at
RMW, she ran several of the citizen science projects, assisted in fund-raising opportunities and membership management, as well as, contributing to other RMW campaigns. Alison received her B.S. in Wildlife Conservation and Entomology from the University of Delaware and is now a Master's candidate in the Environmental Management program at Duke University.

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ABSTRACT

We monitored low-mobility vertebrate species before construction of wildlife crossing structures on the I-90 Snoqualmie Pass East project in the Washington Cascades. Our objectives were to address connectivity patterns and habitat requirements of low-mobility wildlife species, given the likely barrier effect of I-90. Low-mobility species (defined as those with relatively small daily movements and home ranges, low dispersal capability, or restrictive habitat requirements) are particularly vulnerable to fragmentation by roads and associated human uses of adjacent habitat. Yet most wildlife monitoring efforts along roads have been devoted to larger, more mobile wildlife species. We selected a number of low-mobility focal taxa including fish (trout and salmon), amphibians (frogs, toads, salamanders), reptiles (alligator lizards), and small mammals (pikas), and also measured characteristics of several ecosystems (aquatic and terrestrial), and habitats (talus, coniferous forests, wetlands, and streams). Our overall goals were to map the current distributions of low-mobility species near the I-90 corridor, especially in designated connectivity emphasis areas, to determine where and how frequently they cross the highway, and assess habitat characteristics and requirements. We used a variety of techniques to capture, mark, and track individuals, assess habitat, and collect genetic tissue samples. Capture methods include live-trapping, pitfall trapping, transect surveying, road-cruising, and electroshocking (streams). We marked individual organisms of some species with PIT tags, ear tags, toe clips, or fin clips. Tracking methods included radio-tracking, repeat trapping of marked individuals, and PIT tag readers. Habitat measurements were collected in areas where target species were located.

Ecological connectivity for low mobility species along I-90 east of Snoqualmie Pass has not been completely interrupted by the interstate, but crossings seem to be infrequent. Several marked amphibians (frogs, toads) were documented to cross I-90, as well as nearby forest service roads. No pikas were documented crossing the highway, but pikas do occupy rock patches adjacent to the highway shoulder and stream-side rocks under highway bridges. Alligator lizards were found on the interstate shoulders. Fish were found to pass through some, but not all streams that cross under the highway.

Based on our pre-construction monitoring, we will provide recommendations for habitats built into the crossing structures and adjustments (where possible) to specific locations of some of the smaller crossing structures to link existing populations or critical habitat. The data we have gathered on habitat requirements of low-mobility vertebrates will inform engineers on which microhabitat elements should be included in the crossing structures. We will continue to monitor the movements of low-mobility species during the construction and post-construction phases of this project. Future analysis of genetic samples will allow us to determine landscape-level genetic structure for these focal populations, and assess changes to genetic structure and connectivity after wildlife crossing structures have been implemented.

INTRODUCTION

 Interstate 90 (I-90) has been identified as the largest barrier to the movement of wildlife between protected federal lands in the Cascade Mountains of Washington State (Fig. 1). Federal land management plans have documented that I-90 forms a barrier to wildlife movement, and have identified the need to increase ecological connectivity across the highway (USFS 2000). Improving ecological connectivity will advance federal land management goals by reducing fish and wildlife population isolation (USFS and USFWS 1997) as well as reduce the risks to wildlife and the public from collisions between vehicles and wildlife. A 15-mile highway expansion project (I-90 Snoqualmie Pass East Project) began in 2008 with the main purpose of increasing vehicle travel safety and reducing closures due to avalanches on I-90 over Snoqualmie Pass in Washington State. Structures for wildlife passage were designed and planned at 14 major wildlife crossing areas within the project (WSDOT 2008). The wildlife crossing structures were located and designed with the purpose of increasing safety by reducing collisions between wildlife and vehicles, and to connect habitat that is
Figure 1. Map of publicly owned and managed lands within the project area in Washington State.

Currently separated by the highway. The location of the wildlife crossing structures was based on the identification of numerous Connectivity Emphasis Areas (CEA’s) that were chosen based on historical wildlife crossing areas, geographic features, or hydrologic flow.

A review of recent studies focusing on the effects of roads on a range of different taxa concluded that there is clear evidence for negative effects of roads at the population level (Fahrig and Rytwinski, 2009). However, the evidence for population-level effects of roads in many studies was compromised because the studies were usually not designed to evaluate the effects of roads independent of other variables (Fahrig and Rytwinski, 2009). Very few before–after–control–
impact (BACI) experiments have been conducted to determine the impact of wildlife crossing structures on animal populations, yet are needed to accurately evaluate the efficacy of mitigation structures (Roedenbeck et al., 2007).

In 2008 we began a study to monitor low-mobility vertebrate species before construction of wildlife crossing structures on the I-90 Snoqualmie Pass East project. Our objectives were to address connectivity patterns and habitat requirements of populations of low-mobility wildlife species, given the likely barrier effect of I-90. We defined low-mobility species as those with relatively small daily movements and home ranges, low dispersal capability, and restrictive habitat requirements. These species are particularly vulnerable to fragmentation and isolation by roads and associated human uses of adjacent habitat. We chose vertebrate species to monitor that represented different taxonomic groups and ecological niches. The taxonomic groups represented in our study were fish (trout and salmon), amphibians (frogs, toads, salamanders), reptiles (alligator lizards), and small mammals (pikas). Choosing species that inhabited a variety of different habitats enabled us to monitor species in both aquatic and terrestrial ecosystems as well as in specific habitats such as talus, coniferous forests, wetlands, lakes, and streams. Our overall goals were to assess the current population status and map distributions of low-mobility species near the I-90 corridor, especially in designated connectivity emphasis areas where wildlife crossing structures are planned. To accomplish this goal we attempted to determine where and how frequently each species crosses the highway, as well as to assess each species’ habitat characteristics and requirements. In addition to direct measurements of individuals and habitats, genetic samples from each species are being collected for future analyses of the populations.

METHODS

We conducted monitoring of each taxonomic group within the 15-mile project area (Fig. 2) using a variety of techniques to capture, mark, and track individuals, assess habitat, and collect genetic tissue samples as described below in more detail for each group. Capture methods included transect surveying and road-cruising to locate and hand-capture individuals, electrofishing, live-trapping, and pitfall trapping. We marked individual organisms of some species with ear tags, toe clips, or fin clips. Passive integrated transponder (PIT) microchip tags were implanted to monitor movements of most focal species, and radio-telemetry was used to track movements of two amphibian species. Habitat measurements were made using a variety of methods depending on the habitat type. Genetic samples were collected from individual animals by removing small tissue samples from live animals, or by collecting hair samples or fecal pellets. We used hand-held GPS units to record the specific locations of captured and observed animals, and to map distribution, home range, and habitats.

Fish

We established permanent transects in nine study streams for the collection of baseline data on stream habitat and fish populations. Baseline stream habitat conditions included measurements of instream habitat (substrate and woody debris), channel morphology, flow velocity and water temperature. Treatment reach transects were established immediately upstream and downstream of the highway and control reach transects were placed upstream out of the influence of the highway (50-100 meters) with a similar configuration of transects as though a culvert or bridge were present (Fig. 3). We monitored fish populations by conducting surveys in the treatment and control reaches using a backpack electrofisher and dipnets in eight of the streams (Swamp Creek, Bonnie Creek, Noble Creek, Price Creek, Townsend Creek, Resort Creek, Rocky Run Creek, and Coal Creek) (Fig. 2). All captured fish were identified, enumerated, measured for total length, and then released near their original capture location. We sampled Gold Creek by conducting underwater snorkel surveys rather than electrofishing due to the presence of federally-listed bull trout (Salvelinus confluentus). All fish encountered were identified and enumerated, and we visually estimated total length and recorded GPS location for all bull trout.

We marked fish longer than 150 mm (total length) that were captured during the electrofishing surveys with a PIT tag to monitor movements and growth when recaptured. The tags were inserted using standard Biomark® implanters by first anesthetizing the specimens in a solution of MS-222 and then inserting the implanter needle just under the skin on the fish’s ventral side just anterior of the vent and allowing the tag to enter the body cavity. Each PIT-tagged fish was scanned to record the tag code prior to releasing the fish back into the stream. All captured fish were scanned to detect tags that had been implanted during previous surveys. Snorkel surveys and foot surveys were conducted in Gold Creek to determine the timing of bull trout and kokanee salmon (Oncorhynchus nerka) migrations as well as to delineate spawning areas. The surveys began each year in July and continued through November on a 2- to 3-week time interval. GPS coordinates were recorded where either individual bull trout or bull trout redds (nests) were found. We delineated spawning areas used by kokanee salmon in lower Gold Creek by recording GPS coordinates at the upstream and downstream limits of where spawning individuals were found.

Genetic samples were collected from all fish larger than 100 mm by removing a small piece of caudal fin (~0.5 cm²) tissue from the ventral lobe using forceps and scissors. Each tissue sample was then placed in a labeled vial containing 70% ethanol for long-term storage.
Figure 2. Map of the study area showing the locations of species monitoring sites.
Amphibians

The monitoring of amphibians involved many species at many different sites and has used several approaches including radiotracking of individuals, direct monitoring of movements across roads via driving surveys, PIT tagging and marking individuals on either side of I-90 at CEA’s, and genetic sampling.

Three focal species (Cascades frogs, Western toads, Pacific Giant salamanders) were monitored with the aim of (1) characterizing the viability of these populations and (2) estimating the current rate of movement of these species across I-90, especially at three CEA’s (Gold Creek, Swamp Creek, and Toll Creek). In addition, other species were captured opportunistically, especially as they were collected in the driving surveys. Once captured, a genetic sample was collected from many individuals with an emphasis on collections north and south of the CEA’s. In order to identify locations within the vicinity of I-90 study area where Western toads were most likely to be encountered, night-time driving surveys were conducted by 1-2 people on a forest service road located ≤1 km north of the freeway. The road runs parallel to the interstate for 16 km and consists of 11 km of gravel surface with 1 km of paved surface at the eastern end and 5 km at the western terminus. Habitat surveys were conducted in areas where amphibians crossed in high numbers (“hotspots”) and adjacent control sites to identify habitat features (vegetation, canopy cover, slope, aspect, etc.) that might be influencing amphibian movements. We used radio transmitters to track populations of Western toads within the study area. These toads have been tracked from their breeding sites or summer foraging ranges, to overwintering sites and will be tracked back to breeding sites in the springtime. The study area for radio-tracking extends from Swamp Lake to Mardee Lake, with one site south of I-90 near Keechelus dam. Upon encountering a toad it was weighed and snout-to-vent length measured and a PIT tag (Biomark®) implanted into the dorsal lymph sac. A Holohil® BD-2 radio transmitter was mounted to a plastic belt made of 2.6 mm diameter surgical tubing that was custom fit to each toad’s waist with a plastic barbed connector. Toads were tracked using a Telonics® TR-4 receiver with a Telonics® RA-17 directional antenna. Individuals were tracked 2-4 times per week. Upon each encounter, we recorded GPS location, micro habitat information (percent ground cover of leaf litter, moss, rocks, grasses and sedges, herbaceous plants and shrubs), macro habitat information (cloud cover, air temperature, canopy cover, weather conditions), and time of day. Approximately twice a month, snout-to-vent length and mass were measured and the belts were examined to ensure a “good fit”, and to check for abrasions.
To investigate Pacific Giant Salamander movements, habitat use and activity patterns we utilized radio transmitters. Tracking was conducted in and around the surrounding uplands of two streams that have been identified as harboring salamanders and cross I-90: Noble Creek and Wolf Creek. Terrestrial adult salamanders were hand-captured during night surveys in the uplands surrounding the streams. Nine individuals weighing > 40g were implanted with internal radio transmitters for tracking using standardized surgical procedures. During implantation surgery and once per season salamanders were weighed and measured. Salamanders were located every three days during the summer, fall and spring seasons, and twice per month in the winter. Salamander locations were marked with flagging and the position of the salamander (above-ground, under-cover, or under-ground) recorded. To test salamander habitat use and movement correlations we measured environmental variables (temperature, cloud cover, precipitation level, ground cover at each salamander location (1-m circular plot, visually estimated to the nearest 5%), the decay class of woody material, size of cover object and linear distance to water. Each use location was paired with a randomly selected non-use site. Non-use site was determined by taking a random distance (between 1-12 m) and compass bearing from the salamander use location. Ground cover and wood decay class was measured in these non-use sites to test if salamanders are selecting for specific habitat features. Road crossings was recorded as ‘at grade’ or ‘below grade’ when observed. Use or avoidance of existing road crossing structures (steel culverts) was recorded. A combination of tape and compass and Topcon GPS unit were used to map the salamander locations.

Lizards

We initiated a monitoring program for the Northern Alligator lizard (Elgaria coerulea) near the Price-Noble CEA, a location where large terrestrial crossing structures will be built over I-90 near Snoqualmie Pass. We constructed 18 pitfall trap arrays along I-90 in upland forest near Price/Noble Creek: eight on the westbound side of the highway and eight on the eastbound side. Each pitfall array consisted of four 5-gallon buckets buried in the ground up to their rims and connected via smooth aluminum drift fences. Drift fences served to guide lizard moving through the forest into the buried pitfall buckets (Fig. 4). Pitfall arrays were checked several times/week throughout the summer of 2010. All lizards captured were marked with PIT tags (Biomark®), measured, weighed, and released. From these data, we determined the basic population structure of alligators lizards in the project area. Genetic samples were collected from Alligator lizards captured in the pitfall traps; tissue samples were also stored from many of the small mammals captured in the pitfall traps. Habitat variables (canopy cover, understory vegetation, rock abundance and sizes, slope, etc.) were recorded at each pitfall array. These same habitat features were also recorded from other sites within the project area (but outside of the pitfall arrays) where Alligator lizards were encountered. Sites where Alligator lizards were located were then compared with paired sites located randomly within the potential home range of each alligator lizard encountered. The occupied sites were then analyzed along with the random sites to identify specific habitat features associated with the presence of Alligator lizards. We used non-parametric goodness of fit tests, paired t-tests, and correlation analyses to determine specific microhabitat features associated with alligator lizards. These habitat features can then be used to inform the design and construction of future crossing structures. After the structures are built, we can then test their effectiveness by using future pitfall arrays to monitor alligator lizards in a manner similar to what we have described above.

Pikas

Monitoring American pikas (Ochotona princeps) consisted of mapping suitable habitat patches (natural talus and other rocky sites), surveying for pika presence, habitat surveys, live-trapping, and collecting genetic samples. We located and mapped rocky habitats potentially suitable for pikas by aerial photos, scanning the landscape from open vantages points, driving along Forest Service Roads, and hiking across areas suspected to contain talus. We began by mapping as many talus patches as possible within approximately 1-2 miles of the interstate, along the 15-mile project area. However, during the first year, we realized that pikas also inhabited anthropogenic rocky habitats in the project area. These human-made sites include rocky fill placed along roads (I-90, Forest Service roads, and railroad beds) to stabilize slopes, and rocky riprap placed along stream banks to stabilize slopes under bridges. Thus we expanded our habitat searching to include these anthropogenic habitats. We have now mapped 94 rocky habitat patches that are potentially suitable for pikas.

At most of the rocky patches we have identified and mapped, we conducted talus occupancy surveys to verify which patches were occupied by pikas each year. During 2008, we noted whether pikas were seen or heard, and whether we observed any signs of occupancy (“haypiles” of vegetation made by pikas to serve as a winter food store, and pika latrine areas where they commonly defecate; both are signs that pikas have a territory on the patch). Because pikas are diurnal (active during the day), make foraging trips above ground, and make distinctive vocalizations, we were able to readily detect their presence. A patch was considered occupied if pikas were seen or heard, or if fresh (this year’s) haypiles or latrines were observed. During 2009 and 2010, we followed strict occupancy survey protocols using a modification of occupancy surveys developed by the California Pika Consortium (Millar 2010) and the National Park Planning and Designing Effective Crossings 577 ICOET 2011 Proceedings
Figure 4. Pitfall array used to capture alligator lizards along I-90 near Snoqualmie Pass, WA.

Service (NPS 2010). These involved timed focal observations for pika sightings and vocalizations, and walking transect lines across the habitat patch to search for haypiles and latrines. Not all patches were surveyed each year, but some were surveyed for two consecutive years (2008 and 2009 or 2009 and 2010) and some were surveyed all three years. In 2009 and 2010, most surveyed patches were visited in early summer and again in late summer to early fall.

We collected habitat data at a subset of the rocky patches. In 2008, we measured habitat variables at the 9 patches where we trapped pikas (and thus pikas were known to occur), and in 2009 at 4 other patches occupied by pikas. For each patch, we roughly estimated patch size (length, width) and isolation (distance to nearest other talus patch) by pacing off distances or, where possible, measuring with 30-m tapes. At four locations within each patch, we measured slope angle (with a clinometer), slope aspect (compass orientation), and percent canopy cover (with a spherical densiometer). Rock size was measured along a 10-m transect centered on the location and oriented in a random direction. Rock length, width, and height were measured for the rock closest to each meter mark along the transect.

In 2010, we initiated a specific habitat comparison of pika-occupied and unoccupied natural talus patches with anthropogenic rock patches (road-fill and riprap) to characterize the important habitat features of pika-suitable patches. Our study design was to compare 4 sites that were occupied by pikas and 4 sites not occupied by pikas for each of the 3 habitat types, for a total of 8 x 3 = 24 sites. However, most of the natural talus sites were occupied by pikas and we were able to find only 2 unoccupied sites (at elevations similar to the other sites), giving us a total of 22 sites. Most sites were within 1 mile of I-90, and all within an elevation range of 736-1220 m above sea level. At each site surveyed, we recorded GPS locations at the patch center. We recorded patch type (natural talus, road-fill, riprap), patch area, directional aspect, slope, distance from patch center to available forage, depth of deepest crevices between creaks, and distance from the patch edge to the nearest potential pika habitat (talus or other rocky habitat).
We measured the size (longest dimension) of the 10 largest rocks at the patch. We also measured canopy cover using a densitometer, and visually estimated percent ground cover by rocks, lichens, mosses, ferns, grasses, forbs, shrubs, and trees in circular plots.

We selected a subset of the patches known to be occupied by pikas for live-trapping. The main objectives of live-trapping were to mark individuals to monitor any movement between patches, to monitor residency over time (between years), and to collect genetic samples. The patches selected for trapping were either near CEAs to monitor any movements of pikas close to the interstate, or where pikas were abundant (and could potentially provide more genetic samples). At each trapping location (patch), Tomahawk live-traps were placed in clusters around sites where pikas or their sign (latrines, haypiles) were seen. Fresh vegetation from the edge of the patch was used as bait. Captured pikas were weighed, marked with ear tags (in 2008-2009) or hair dye (2010), and implanted with a uniquely coded PIT tag (Biomark®) (2009-2010), then released at the site of capture. To minimize stress, we anesthetized the animals with isoflurane before handling. We collected small ear tissue samples (from the ear tag punch or an ear notcher) from each captured animal. Trapping was typically conducted for a 3-day period at each site, during morning and evening hours. We trapped at 9 sites in 2008, 4 sites in 2009, and 2 sites in 2010.

Genetic tissue samples collected from live-trapped individuals (as described above) and stored dry in coin envelopes. We also collected fresh fecal pellets during habitat surveys, and placed them in buffer until initial DNA extractions. We also conducted a trial of hare snares at active haypiles using packing tape placed sticky-side out on a web of fishing line at the entrance to the haypile (Henry and Russello 2009).

RESULTS AND DISCUSSION

Fish

Based on direct observations of certain fish species as well as the recapture of tagged fish we found that the highway is not a barrier to fish passage in some streams, but may be a barrier in others. In Swamp Creek we found juvenile Chinook salmon in 2008, 2009, and 2010 upstream of a concrete culvert under I-90. The nearest spawning area for Chinook salmon is about 200 meters downstream in the mainstem Yakima River, so the juveniles likely migrated upstream into Swamp Creek during the moderate stream flows in early summer when passage through the culvert is possible.

In contrast to Swamp Creek, we found no movement of cutthroat trout (*Oncorhynchus clarki*) tagged with PIT tags in Rocky Run Creek. We recaptured 13 cutthroat trout in 2010 out of 50 that had been tagged in 2009 (26% recapture rate), however, all of the recaptured fish were found in their original capture/release location with no evidence of any fish moving through the culvert under I-90. We also found that both bull trout and kokanee salmon were able to move past the I-90 bridges in Gold Creek (Fig. 5) to make successful spawning migrations. Bull trout redds were found several kilometers upstream from I-90, and kokanee salmon used the areas immediately under and adjacent to the I-90 bridges for their redds.

New bridges are currently being constructed over both Rocky Run Creek and Gold Creek to make the span longer and allow the streams to create a more natural channel. The pre-construction data on seasonal cutthroat trout movements in several of the study streams as well as bull trout and kokanee salmon spawning migration patterns in Gold Creek will be compared to similar data collected following the completion of the new bridges to evaluate the efficacy of the structures for improving ecological connectivity. A genetic analysis of the fish populations in each stream prior to and following construction of stream-crossing structures will also help to assess any changes in ecological connectivity.

Pre-construction stream habitat data will be compared to similar data collected following the completion of stream-crossing structures to assess habitat responses when culverts are replaced with bridges. Channel shape, flow regime, substrate composition and woody debris are variables that are likely to change when stream channels are allowed to flow unrestricted instead of through culverts. The highway construction project includes plans to replace culverts and short bridges over several streams of varying channel widths with bridges of varying span lengths, so post-construction data will be useful in determining which streams and associated bridges respond positively with respect to instream habitat, fish passage, and overall stream health.
Amphibians

Among focal amphibians, Cascades Frogs are relatively abundant throughout the study area and adult recapture rates were 74% at Gold Creek with all tagged individuals were recovered at Swamp and Toll Creek. Cascades frogs tend to occupy stream channels, wetlands, or riparian areas. The high frequency of tagged individuals allowed us to detect movements across I-90, suggesting limited connectivity for amphibians at Toll Creek and Swamp Creek. At Swamp Creek, we detected 7 and 5 Cascade frogs move across I-90 through a box culvert in 2009 and 2010, respectively. Similarly at Toll Creek, we detected 2 and 3 individuals move through a pipe culvert in 2009 and 2010, respectively. Detections at
Toll Creek were made with an automated PIT detector that was installed in Toll Creek. For the Gold Creek CEA, movement of amphibians across I-90 may be constrained by the Gold Creek bridge and the parallel forest service bridge. We expect permeability in this region to increase with the construction of a raised bridge and restoration of Gold Creek to a more natural flow regime. Western toad detection at these sites was low. However, tracking of toads by radio telemetry suggests they can move long distances and spend most of their time in the uplands outside of breeding the seasons.

We tracked 25 different Western toads from the fall of 2009 to the spring of 2010. Toads were observed mostly using burrows and tunnels in roadside ditches and hillsides less than 3 m from Forest Service Road 4832. Further, they frequently cross FS Road 4832 and were routinely found during nighttime road surveys on the surface of the road. Three of the radioed toads were run over by cars on FS Road 4832 during 2010. However, Toads do appear to avoid I-90 and were only rarely observed coming within 3 m of the roadway.

Terrestrial Coastal Giant salamanders (N=7) were radiotracked from the spring of 2010 until spring 2011. All of these salamanders were encountered on or within 1 m of Forest Service road 4832 during rainy spring nights. Three tracked salamanders were observed crossing FS Road 4832 at grade. One salamander travelled to within 1 m of I-90 but made movements parallel to the highway.

Overall, there is limited connectivity of Cascade frogs across I-90. However, Western Toads and Coastal Giant salamanders appear to avoid I-90. However, they do interact with a forest service that runs parallel to I-90.

Lizards

Northern Alligator lizards are relatively abundant on both sizes of I-90 in the vicinity of the Price/Noble connectivity emphasis area (CEA). Pitfall arrays were successful in sampling not only Alligator lizards, but also small mammal species such as shrews. Several amphibians (frogs, toads, and Ensatina salamanders) were also captured in the pitfall arrays. The Alligator lizard population structure, based on preliminary data from the first field season, suggests a robust population with varies age classes (juveniles, early reproductive adults, and larger adults) well represented in the population. The age and sex of individuals that are active in the population varies seasonally, with females more active in the summer and males and juveniles more active in the early fall. This suggests that the timing of sampling is important; an incomplete understanding of population characteristics might result from a limited sampling period. Very few individuals were recaptured during our first year of sampling with pitfall traps. As more individuals become marked in the population, and subsequent seasons are added to our analysis, we should obtain more recaptures and be able to more accurately estimate the population density of Alligator lizards at the connectivity emphasis area.

Certain microhabitat features of sites used by Alligator lizards differed significantly from random locations within the connectivity emphasis area. Alligator lizards selected microhabitats with relatively low forest canopy cover (30-60%) and moderate rock cover (6-15%) and more medium (10-30 cm) to large-sized (>60 cm) rocks. Sites occupied by Alligator lizards varied in understory vegetation, with low-growing kinnikinnick (Arctostaphylos uva-ursi) being the most abundant. However, we found no significant differences in understory vegetation between Alligator lizard sites and random sites during this first field season.

The information from this study will facilitate design of wildlife crossing structures to include microhabitat features that enhance movements of low mobility species in this area. Our results are only preliminary; additional field seasons are necessary for a valid sample size and to capture inevitable annual variation. Based on our preliminary results for Alligator lizards, moderate understory rock cover (6-15%), a variety of rock sizes (especially intermediate-sized rocks, 10-60 cm in diameter), and 30-60% forest canopy cover may be important microhabitat features to design into the crossing structure at Price/Noble CEA. A more complete picture of understory vegetation requirements and Alligator lizard movements will come with additional field seasons.

Studies should be continued and after construction to determine the effectiveness of the bridges as sources of habitat for wildlife migration. As future terrestrial crossing structures are built, pitfall trapping arrays can be incorporated into those structures to monitor their use and effectiveness in enhancing connectivity of low mobility terrestrial vertebrates.

Pikas

We have mapped 94 rocky habitat patches that are potentially suitable for pikas within the project area (Figure 6). Pikas occupy 80-95% of suitable rock patches in the study area, including anthropogenic habitats such as patches of rocky road fill along the shoulders of highways and Forest Service roads and riprap along streams. The high occupancy rate suggests that, despite the strong tendency of adult pikas to stay in established territories and disperse infrequently
Figure 6. Rocky habitat patches potentially suitable for pikas, including natural talus (NT) and human-made patches (rocky fill along roads or railroads, RF, and riprap, RR). M = mixed types.

(Barash 1973; Tapper 1973; Smith and Ivins 1983), pikas (perhaps the young?) are able to disperse among patches on one side of the interstate or the other side. This is supported by genetic analyses of pikas in fragmented habitats suggesting that gene flow does occur among patches in fragmented habitats (Peacock and Smith, 1997).

Our preliminary data do not yet allow us to evaluate whether pikas are currently able to cross the interstate. So far, we have no observations of pikas moving across the interstate at grade level or of being killed on the highway, and no records of PIT-tagged individuals being recaptured on the opposite side. Pikas have been seen running across small gravel forest service roads on at least two occasions in the past three years by our field crews, but these are much narrower roadways with a more natural surface, often overhanging vegetation (shrubs or trees), and very little traffic. Given the susceptibility of pikas to heat stress and predation (Smith and Weston 1990), the likelihood of them successfully crossing multiple lanes of highway (often with high traffic volumes) is probably quite low. However, pikas do occupy rock riprap under highway bridges at one site (Gold Creek), and there is no apparent barrier to them moving across the highway below grade level at that location.

Our habitat analyses suggest substantial overlap in habitat features of natural talus and anthropogenic rocky patches occupied by pikas. However, some differences do exist among patch types and between occupied and unoccupied patches, such as in patch size, number of vertical rock layers, canopy cover, and maximum rock size. We will be able to provide recommendations to WSDOT on habitat features to incorporate into crossing structures where pikas are a likely candidate for crossing (i.e., structures that incorporate rock piles or other talus-like habitat). We can also use the
habitat data to suggest engineering specifications (such as rock size, depth of rocks) for rocky road-fill along the highway and riprap under bridges where encouraging pika colonization is considered beneficial.

To date, we have collected genetic samples from 52 individuals north of I-90, 45 individuals south of I-90, and 14 directly under I-90 (riprap sites). We will continue to build the tissue collection, and will conduct landscape-level analyses to see if I-90 has likely been a barrier to pika movement in the past. Genetic samples collected in the future after wildlife crossing structures are implemented can be used to compare with current levels of genetic structuring in pika populations, and hopefully evaluate the effectiveness of the crossing structures in improving connectivity.

CONCLUSIONS

Our data on these low-mobility species suggests that their ecological connectivity has not been completely interrupted by I-90 east of Snoqualmie Pass, but crossings seem to be infrequent. Some amphibians (frogs and toads) were documented to cross I-90, as well as nearby forest service roads. Alligator lizards occur along the highway shoulders at Price-Noble. No pikas were documented crossing the highway, but pikas do occupy rock patches adjacent to the highway shoulder and stream-side rocks under highway bridges. Fish passage under the interstate occurs in some, but not all, streams that cross under the highway.

Based on our pre-construction monitoring, we have and will continue to provide recommendations to the state department of transportation for habitats built into the crossing structures. In addition, our mapping of habitats and species occurrences will allow us to recommend adjustments (where possible) to specific locations of some of the smaller crossing structures (e.g., culverts) to link existing populations or critical habitat. The data we have gathered on habitat requirements for these low-mobility vertebrate species will inform engineers on which microhabitat elements should be included in the crossing structures.

Monitoring multiple focal species of small vertebrates across highways presents multiple challenges in study design and logistics. We were able to solve many of these issues in the first three years of pre-construction monitoring, but in some cases low sample size (due to logistics and budgetary constraints) continues to make robust data analysis and conclusions a challenge. For many of these smaller vertebrates, direct observations of animal movement across the highway are difficult, thus our reliance on indirect measures in most cases. Highway crossings by amphibians and fish seem to be easier to detect, at least in part because PIT-tag antenna arrays have been installed in smaller culverts and under highway bridges.

Studies of this nature encompassing a variety of species and approaches, and attempting to provide data needed by the state department of transportation, require a high level of cooperation among researchers and agencies. Our biological work has been supported by positive interactions with the regional land management agency involved in permitting the I-90 construction (the US Forest Service, Okanagan-Wenatchee National Forest, Cle Elum Ranger District) and by the highway agency (WSDOT). We highly recommend developing cooperative interagency agreements and interactions.

Future Work

Results collected to date will help us fine-tune pre-construction monitoring protocols for the next 10-mile section of the Snoqualmie Pass East Project, which has not yet been funded. We will continue to monitor the movements of low-mobility species during the construction and post-construction phases of this project.

We plan some experimental manipulations to test ideas generated from observational monitoring data. Field experiments will be especially useful for testing specific aspects of habitat that our monitoring study suggest may be requirements for some of our focal species. For example, pre-construction monitoring has indicated that patch size, number of vertical rock layers, and maximum rock size may be important for pikas. We are designing experiments to create replicated rock patches with different combinations of habitat variables and hope to monitor pika colonization of these new patches.

We will continue to collect genetic samples. Analysis of genetic samples will allow us to determine landscape-level genetic structure for these focal populations, and assess changes to genetic structure and connectivity after wildlife crossing structures have been implemented.
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REFERENCES


E **lk Movements Associated with Interstate-17 in Northern Arizona**

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**ABSTRACT**

Collisions with wildlife, particularly elk (Cervus elaphus), along Interstate-17 (I-17) south of Flagstaff, AZ USA are a significant safety concern. To address this, we worked with Arizona Department of Transportation to obtain information on elk movements and wildlife-vehicle collisions (WVC) to inform the early planning stages of reconstruction. Our objectives were 1) assess elk movements and distribution associated with I-17, 2) investigate relationships of elk highway crossing and distribution to traffic volume, 3) investigate WVC patterns and traffic volume relationships, 4) investigate elk crossings and WVC in relation to meadow and riparian habitat, and 5) develop strategies for wildlife passage structures and fencing to reduce WVC and promote wildlife permeability across I-17. We obtained 297,283 Global Positioning System (GPS) relocations from 71 collared elk. Elk crossed I-17 912 times, indicating a substantial barrier to elk movement, particularly when compared to SR 260 where elk crossed >11,000 times. Passage rates averaged 0.09 crossings/approach, and were substantially lower than those along SR 260, where they averaged 0.50 crossings/approach overall and as high as 0.88 crossings/approach along 2-lane sections of roadway. At-grade elk crossings were likely deterred by traffic along I-17, which averages approximately 17,000 vehicles/day versus <8,000 vehicles/day along SR 260. We identified a large peak in crossings (29% of all crossings) along a 3.2 km stretch of road with a wide median. Passage rates in areas with standard medians (≤70m) averaged 0.06 crossings/approach, but increased to as high as 0.21 crossings/approach with >140m medians. Another peak in crossings occurred near an existing structure that has been in place for over 30 years. The success of this structure in providing safe passage for elk provides insight into the potential success when wildlife crossings are incorporated into future reconstruction. Due to minimal I-17 crossing data, our ability to predict high crossing locations along I-17 using a model derived from SR 260 was limited. Although we recognized general trends, further validation using highways with similar habitat characteristics will be required to determine predictive ability of this model. Considering the liability incurred by transportation agencies when dealing with WVC, each highway should be evaluated on a case-by-case basis as traffic volumes and habitat types play an important role in wildlife attempting to cross highways. We documented 395 WVC, with elk accounting for 80.0%. We identified peaks associated with riparian-meadow habitat and sections of highway with wide median, indicating habitat preference and road configuration influenced WVC. Using our GPS movement data, combined with other important criteria, we identified locations along I-17 where future wildlife crossings should be considered. Arizona Department of Transportation is seeking a long-term solution to address WVC and will consider information from this project for planning efforts. GPS technology has constituted a valuable tool, facilitating understanding of wildlife-highway relationships and promoting a safer and more ecologically sensitive roadway.

**INTRODUCTION**

Highways constitute one of the most significant forces altering natural ecosystems in North America (Noss and Cooperrider 1994, Trombulak and Frissell 2000, Farrell et al. 2002, Forman et al. 2003). Direct mortality from wildlife-vehicle collisions (WVC) has been recognized as a serious and growing threat to wildlife populations as well as contributing to human injuries, deaths, and property loss (Schwabe and Schuhmann 2002, Bissonette and Cramer 2008). More than 38,000 human deaths attributable to WVC occurred in the United States between 2001 and 2005, and the economic impact of these collisions exceeds $8 billion/year (Huijser et al. 2007).

Indirect barrier effects associated with highways pose an even greater impact on wildlife than WVC and for many species these pervasive impacts have contributed to fragmentation and diminished habitat connectivity (Noss and Cooperrider 1994, Forman and Alexander 1998, Forman 2000, Forman et al. 2003, Bissonette and Adair 2008).

The integration of structures designed to reduce WVC and promote wildlife passage across highways in transportation projects has increased in the past decade (Bissonette and Cramer 2008). Passage structures have shown benefit in promoting passage for a variety of species (Farrell et al. 2002; Clevenger and Waltho 2003, Dodd et al. 2007a), and in conjunction with fencing have dramatically reduced the incidence of WVC (Clevenger et al. 2001, Dodd et al. 2006, Olsson et al. 2008, Gagnon et al. 2010a).

Along with structural characteristics, proper location and placement of wildlife crossing structures are vital considerations to maximizing wildlife use (Reed et al. 1975; Foster and Humphrey 1995; Clevenger and Waltho 2000, 2003; Dodd et al. 2007b; Gagnon et al. 2011). The availability of wildlife movement data and highway crossing information obtained with Global Positioning System (GPS) collars (Dodd et al. 2007c, Gagnon et al. 2010b, Clevenger and Huijser 2011), along with spatially accurate WVC data (Gunson et al. 2009) are valuable tools in developing comprehensive strategies and locating passage structures such that their success is maximized in promoting permeability and highway safety (Gagnon et al. 2010b).

In Arizona, the incidence of WVC along a 53 km stretch of Interstate-17 (I-17) south of Flagstaff is a significant concern, and one that would potentially worsen as Arizona continues to grow and traffic on I-17 increases. With long-range plans for reconstruction of I-17 to address increasing traffic volumes and highway safety issues, Arizona Department of Transportation (ADOT) anticipated the need to address WVC issues, particularly those involving elk, and funded an elk movement study in 2006. Preliminary data indicated that, with its high traffic volume, I-17 is a significant barrier to wildlife passage (Gagnon et al. 2008). Theoretical models predict that highways at ≥10,000 Average Annual Daily Traffic (AADT) are impermeable barriers to most wildlife species (Seiler 2003; Iuell et al. 2003). Interstate-17 regularly exceeds these levels and between human population growth and ADOT’s planned upgrades, traffic volumes are projected to be between 24,000 and 48,000 AADT by 2029 (ADOT 2009).

In 2006, ADOT began environmental surveys and development of a Design Concept Report (DCR) to address planned reconstruction of the segment immediately south of Flagstaff, AZ. Preliminary crash data analysis along this section indicated that WVC accounted for the highest percentage of all accidents northbound (21.2%), and the second highest percentage of all accidents southbound (20.4%, second only to overturning at 22.6%). The National average for wildlife-related accidents is 4.6% -5.0% (Huijser et al. 2008, Clevenger and Huijser 2011; Figure 1). This information has been crucial to the ongoing design concept study and development of a DCR for the eventual reconstruction of I-17.

Aside from the WVC data, additional site-specific information on elk movement patterns is crucial to the process of making informed, data-driven recommendations for wildlife passage structures and other mitigations. To supplement the WVC data and provide the best available information to the planning team to make decisions on wildlife crossing structure locations and fencing, ADOT funded Arizona Game and Fish Department (AZGFD) to conduct an elk (Cervus elaphus) movement study in 2008. The specific objectives of this research project were to:

- Assess elk movements, highway crossing patterns, and distribution; determine permeability of the highway corridor.
- Investigate spatial and temporal relationships between traffic volume and
  - elk distribution patterns;
  - elk highway crossings;
  - elk-vehicle collision (EVC) patterns.
- Investigate elk crossing patterns and EVC in relation to meadow and riparian habitats through the refinement and validation of the riparian-meadow habitats influence model developed for SR 260 (Manzo 2006).
- Develop strategies for wildlife passage structures and other measures (e.g., fencing) to reduce WVC and promote wildlife permeability across I-17.

We briefly address the findings of this study here, further details can be found in Gagnon et al. (2011a).
STUDY AREA

We conducted our study along a 48-km stretch of I-17, immediately south of Flagstaff, AZ. Interstate 17 is the primary highway artery between Phoenix and northern Arizona. The study area lies at the southernmost extent of the Colorado Plateau and varies in elevation from 1,623 m at the southern extent to 2,133 m near Flagstaff. The study stretch of I-17 was identified as Linkage 23, Oak Creek Canyon-Munds Park in the Arizona’s Wildlife Linkages Assessment (ADOT 2006), where the primary threats were associated with the upgrade of I-17 and private land development. Land ownership adjacent to the I-17 corridor is dominated (>90%) by U.S. Forest Service (USFS; Coconino National Forest), with limited private land holdings.

Ponderosa pine (*Pinus ponderosa*) dominates the northern two-thirds of the corridor which lies above the Mogollon Rim with numerous wet meadow-riparian habitats immediately adjacent to or near the highway corridor. These likely influence elk distribution and movements as seen on SR 260 (Manzo 2006, Dodd et al. 2007a). This forest-meadow complex provides summer range for elk and other wildlife. Below the Rim, sparse juniper (*Juniperus* spp.) dominates the southern third of the corridor providing intermediate and winter range to elk and other wildlife species. For most of its length through the study area, I-17 is a four-lane divided highway with a standard median less than 70 m in width. However, at two places, the median exceeds 150 m in width. Most notably however, is a 4 km section of highway where north and southbound lanes are separated by more than 760 m. This extreme separation is potentially significant as the highway functionally becomes two separate two-lane highways with half the traffic volume. This resulting road configuration could affect wildlife approaches and crossings, road mortality, and the intensity of the barrier effect along this portion of the highway. (Jaeger et al. 2006).

The focal species of this study was elk given that this species accounts for >75% of all WVC along this stretch of I-17. Above the Mogollon Rim, elk are found in moderate densities as the highway passes through elk summer range. Below the Mogollon Rim, elk densities in the intermediate and winter range along I-17 are dependent upon the amount of winter snow.

METHODS

From 2006-2010 we captured elk at 33 trap sites adjacent to I-17 stretching approximately 43 km south of Flagstaff, AZ, USA in net-covered Clover traps (Clover 1954) baited with salt and alfalfa hay. We instrumented elk with GPS collars programmed to receive relocations every two hours; battery life for the GPS units was approximately two years. We used ArcGIS software (ESRI, Redlands, California) to analyze GPS data to inform recommendations for the placement of wildlife crossings structures. Our evaluation of highway permeability and its' relationships to traffic
Assessing Elk Movements along Interstate-17.

We divided the study area into 450 sequentially numbered 0.16 km segments corresponding to the 0.1 mile units used by ADOT for tracking WVC and highway maintenance, and identical to the approach used by Dodd et al. (2007a,c, 2009a, 2010a; Figure 13). To determine highway crossings, the team drew lines connecting all consecutive GPS fixes and inferred highway crossings where lines between fixes intersected the highway. We used Animal Movement ArcView Extension Version 1.1 software (Hooge and Eichenlaub 1997) to assist in animal crossing determination. The research team compiled crossings by individual animal, highway segment, date and time, and calculated crossing rates for individual elk by dividing the number of crossings by the days a collar was worn.

We calculated the passage rates for all collared elk to serve as the relative measure of highway permeability and allow for direct comparisons to other wildlife-highway projects throughout Arizona (Dodd et al. 2007a,c, Dodd and Gagnon 2011). An approach was considered to have occurred when an animal’s successive GPS fixes indicated that it traveled from a point outside a 250 m buffer zone to a point within 250 m of I-17. The approach zone corresponded to the road-effect zone associated with traffic-related disturbance (Rost and Bailey 1979, Forman et al. 2003) previously used for elk by Dodd et al. (2007a,c, 2009a, 2010a) and Gagnon et al. (2007a, 2010a). Events in which an animal directly crossed I-17 from a point beyond 250 m were counted as both an approach and a crossing. We calculated passage rates as the proportion of highway crossings to approaches for those elk that approached I-17 at least 5 times.

We hypothesized that traffic volume could have a differential impact on elk distribution along stretches of I-17. Wide and extremely wide medians, when compared to standard medians, could simulate differences in the bundling of roads as described by Jaeger et al. (2006), and the traffic volume here might be perceived by wildlife as being lower (e.g., half the combined traffic volume of highway stretches with standard medians). As such, the research team conducted a separate analysis for stretches of I-17 with wide and extremely wide medians.

To assess the effect of median width on elk movement across the highway, we compared mean elk crossing and passage rates among three different I-17 highway median width classes, with the widths measured at each 0.16 km segment by GIS analysis and assigned to these classes:

- **Standard median** (<70 m wide)
- **Wide median** (70–140 m wide)
- **Extremely wide median** (>140 m wide)

We derived values for individual elk approaching and crossing I-17, pooling them by median width class and used ANOVA to test the null hypothesis that no differences in mean elk crossing and passage rates existed as a function of highway width class. When we obtained significant ANOVA results among classes, we conducted post hoc pairwise comparisons using a Tukey test for unequal sample sizes (Statsoft Inc. 1999). We applied arc sine transformations to our passage rate data to allow comparison of proportions and ensure normality in the datasets (Neter et al. 1996).

Based on the conceptual model that suggests highways with traffic volume >10,000 vehicles/day are total barriers to the passage of many wildlife species (Seiler 2003, Luell et al. 2003) and preliminary data that indicated I-17 is a substantial barrier to elk (Gagnon et al. 2008), we anticipated that few collared elk would cross I-17 relative to SR 260 where 100 elk crossed 11,052 times (Dodd et al. 2009a). As such, the team used the number of approaches by elk to within 250 m of I-17 to determine distribution of animals adjacent to the highway for the purposes of assessing the need for and potential locations of passage structures. To account for the number of individual elk that approached each I-17 highway segment, as well as evenness in approach frequency among animals, the research team calculated Shannon diversity indices (SDI; Shannon and Weaver 1949). Weighted highway approaches better reflected the tendencies of the local population with equity in distribution among collared elk (Dodd et al. 2007a, 2009b).

**Spatial and Temporal Relationships of Elk Movements Associated with Traffic Volume**

We measured traffic volume using a permanent automatic traffic recorder located at the mid-point of the study. ADOT’s Multimodal Planning Division Data Team provided the traffic recorder and programmed it to record hourly traffic volumes, vehicle type and speeds. For a direct comparison to other highways in Arizona, we examined how the proportion of elk GPS fixes at different distances from the highway varied with traffic volume by calculating the
proportion of fixes in each 100 m distance band out to 600 m by combining traffic and GPS data (Gagnon et al. 2007a, Dodd et al. 2010). This allowed us to correlate the traffic volumes that each animal experienced during the hour prior to its location at a particular point within 600 m of the road, regardless of distance traveled. We calculated a mean proportion of fixes for all animals within each 100 m distance band from I-17 at varying traffic volumes (Gagnon et al. 2007a). We then compared these results to those for elk on SR 260 (Gagnon 2007a) and SR 64 (Dodd et al. 2010a) exhibiting different traffic volume levels and temporal patterns.

Spatial and Temporal WVC Patterns and Traffic Volume Relationships

We considered WVC along I-17 with analysis of data provided by the Department of Public Safety, ADOT Maintenance, and volunteers. These records were augmented by regular targeted searches of the highway corridor for evidence of WVC by AZGFD personnel. Once these data sources were combined, we removed duplicate entries. We compiled the frequency of WVC for elk 0.16-km segments, and compared the temporal incidence of WVC involving each species among years, seasons, month, day, and time (Dodd et al. 2006, 2007a).

We assessed the number of elk fitted with GPS collars that were involved in EVC as a function of their relative highway crossing frequency, as done for SR 260 by Dodd et al. (2007a). The team compared actual versus expected frequencies of collared elk killed in EVC within these mean highway crossing frequency classes using chi-square analysis.

Evaluating Relationships of Elk Movements and Collisions to Riparian Meadow Habitat

Manzo’s (2006) SR 260 model, specific to riparian-meadow habitats within ponderosa pine forest, found that 85% of all elk crossings were located within 1 km of permanent waters/riparian-meadow habitat. The research team used this model to predict the locations where elk crossings, weighted approaches, and EVC would be expected to occur along segments of I-17 located within ponderosa pine forest along which all riparian-meadow habitats occurred adjacent to the highway. We used GIS to measure the distance from I-17 at each 0.16 km segment to the nearest riparian-meadow habitat using a vegetation cover layer. We then used this information to assess the proximity of the nearest riparian-meadow habitat to I-17 associated with each 0.16 km segment (n = 279).

We conducted chi-square contingency table analysis (Agresti 1996) of the number of 0.16 km segments with and without elk crossings, weighted approaches, and EVC as a function of whether or not segments were within 1 km to the nearest riparian-meadow habitat. We calculated the differences between observed and expected numbers of 0.16 km segments with and without crossings, approaches and EVC, calculated odds ratios reflecting the likelihood that crossings, approaches, and EVC would occur at 0.16 km segments in proximity (<1 km) to riparian-meadow habitat.

Identification of Wildlife Crossing Structure Locations

Utilizing all available information to identify locations of crossing structures is essential to their success (Clevenger and Huijser 2011). We considered criteria identified by Sawyer and Rudd (2005) for our assessment of potential passage structure sites and validation of the DCR preliminary findings. Dodd et al. (2006, 2007a) reported that the optimum scale to address management recommendations for accommodating wildlife passage needs using GPS telemetry or WVC data was at the 1-km (0.6 mile) scale. Making recommendations at this scale allows transportation engineers latitude to determine the best technical location for passage structures along the segment. Thus, we aggregated the 450 0.16-km segments into 75 1-km segments for analysis.

We used several criteria identified by Sawyer and Rudd (2005) with some modifications to rate each of the 75 1-km segments using the elk GPS telemetry findings, WVC incidence, and other pertinent factors such as presence of terrain suitable for passage structures (Clevenger and Huijser 2011), as done previously for SR 64 (Dodd et al. 2010a) and US 89 (Dodd et al. 2009b). Our criteria included the following (for specific ratings within each criteria see Gagnon et al. 2011):

- **Elk highway crossings** – this rating was based on the frequency of I-17 crossings made by GPS-collared elk within each aggregated 1-km segment, and reflected the influence of median width and existing structures.
- **Weighted elk approaches** – this criterion was considered the most important and indicative of where animals approached and would potentially cross I-17 via passage structures, based on SDI weighted approaches.
- **Elk-vehicle collisions** – this criterion was heavily weighted due to the EVC impact on highway safety, and was based upon the number of non-duplicate EVC recorded by 1-km segment during the project.
• **Deer-vehicle collisions** – the number of non-duplicate DVC recorded by 1-km segment during the project.

• **Human activity** – ideally, no human activity should occur within the vicinity of a passage structure; however, road access, businesses, developments, overlooks, and other activities do occur adjacent to I-17.

• **Topography** – the ability to situate overpasses oriented along existing ridgelines that elk, deer or wildlife can traverse, or locate underpasses in association with drainages is desirable.

In addition to the above criteria, we considered other factors for the identification of potential passage structure sites. These factors included whether the 1 km segments coincided with the preliminary sites recommended in the DCR, the types of structures suited for each site, and how the priority segments from this study relate to the minimum recommended passage structure spacing determined by Bissonette and Adair (2008). Once 1-km segments are identified through this process, fine-tuning of locations within each 1 km segment will occur using GPS movement and WVC data to the 0.16 km scale, combined with a field visit (Clevenger and Huijser 2011) to evaluate the locations first-hand and identify its suitability for wildlife crossing.

**RESULTS**

Between March 2006 and October 2010, the research team captured, tracked and recovered data from 71 elk (54 females, 17 males) instrumented with GPS receiver collars. Collars were worn by elk for an average of 473.6 days (±32.2 SE), during which time the collars collected 297,283 GPS fixes for a mean of 4,128.9 fixes/elk (±252.3; Figure 2); 65 of the elk yielded sufficient approaches to calculate passage rates (5 or more approaches). Of the GPS fixes, 77,314 (26.0%) were recorded within 1 km of I-17, and 20,900 (7.0%) of the fixes occurred within 250 m of the highway.

Nearly half of the elk (n=33) never crossed I-17. The collared elk that did cross I-17 northbound (NB) and/or southbound (SB) lanes combined for a total of 912 crossings, or a mean of 12.7 crossings/elk (±3.4), with a range of 2−173 highway crossings/elk; of these crossings, only 29.9% (273; 3.9/elk ±1.1) spanned the entire highway corridor. Elk crossed I-17 0.03 (±0.01) times/day and crossing rates did not differ by sex. The crossing distribution exhibited two large aggregated peak crossing zones (Figure 3); the observed distribution differed from a random crossings distribution (Kolmogorov-Smirnov $d = 0.309, P < 0.001$).

The highest peak crossing zone corresponded to Munds Canyon (MP 322.0), where 11 elk crossed 145 times (16.1% of total) associated with the Munds Canyon bridge. This area accounted for just 1.4% of the total highway length where crossings occurred but accounted for 16.1% of all crossings. The other crossing peak corresponded to the stretch of highway where the lanes were separated by an extremely wide median. Along the 3.2 km stretch with the greatest separation, 261 elk crossings, or 29.0% of the total.

Our assessment of elk crossing rates by highway median width class identified differences among mean crossing rates (ANOVA; $F_{2,100} = 3.2; P = 0.043$). The mean crossing rate for elk using highway segments with the extremely wide medians was four times higher (14.5 crossings/elk) than the crossing rate for the highway with standard median width (3.7 crossings/elk; $P = 0.049$). These two sections constitute only 4.3% of the entire length of highway with elk crossings, yet accounted for 45.1% of all recorded crossings (see Figure 4 for examples). Though the crossing concentrations in these two areas provide meaningful insight into the benefit of an existing bridge adjacent to attractive foraging habitat and widely separated northbound and southbound lanes, they nonetheless are skewed and overwhelm the crossing patterns for elk elsewhere along the highway. As such, the research team also relied upon elk approaches to assess passage structure needs and habitat relationships (see Highway Approaches).
Figure 2. Global Positioning System data from 71 collared elk totaling 287,283 relocations from 2006-2010. The thin black line is I-17 from Flagstaff, AZ to approximately 70 km south. Each color represents individual elk and each dot is a location taken every 2 hours during peak elk activity.
Figure 3. Elk highway crossing (top) and SDI weighted approach (bottom) frequency by 0.16-km segment along I-17 determined from GPS relocations from 71 elk between 2006 and 2010. The 2 peaks on the crossing graph correspond to the extremely wide median and area in close proximity to Munds Canyon Bridge.
Figure 4. Examples of elk GPS movements associated with extremely wide medians (>140 m; top) and standard medians (<70 m; bottom). Interstate-17 is delineated by the red line, GPS relocations are connected from coordinates in 2 hour intervals.
Highway Approaches

Despite the low highway crossing rate, GPS-collared elk were located within 250 m of I-17 a total of 20,830 times, for a mean of 293.4 approaches/elk (±48.3) and a range of 4 to 1,471 approaches/elk, excluding one collared elk that never approached the highway. The spatial pattern of elk approaches adjacent to I-17 differed from a random distribution pattern (Kolmogorov-Smirnov $d = 0.177$, $P < 0.001$), exhibiting several peaks along the highway (Figure 3). These peaks corresponded to the section of highway with the wide median and several meadow complexes above the Mogollon Rim. Those segments which elk approached, had a mean of 50.6 recorded approaches per 0.16 km segment (±3.7), with a range of 1-491; only 44 segments (10.7%) had no elk approaches.

Our application of SDI to calculate weighted approaches for each 0.16-km segment yielded 36,475 weighted approaches, with a mean of 83.7 (±7.0); weighted approaches reduce bias of individual elk movements by accounting for the number of different elk approaching within each segment. The weighted approach distribution also differed from a random distribution (Kolmogorov-Smirnov $d = 0.277$, $P < 0.001$).

Highway Passage Rates

The elk passage rate across I-17 averaged just 0.09 crossings/approach (±0.02). For the elk that crossed I-17 ($n = 38$), the mean individual elk passage rates ranged from 0.01 to 0.61. The passage rate for males (0.11 crossings/approach ±0.03) was comparable to that of females (0.09 crossings/approach ±0.02). When evaluated by highway median width class, we found differences among the mean passage rates (Table 4; ANOVA; $F_{2,99} = 6.9; P = 0.002$). The mean passage rate for elk using highway segments with extremely wide medians was three times higher (0.21 crossings/approach) than the passage rate for elk using the highway with standard median width (0.06 crossings/approach; $P = 0.011$). The mean combined passage rate for highway with wide and extremely wide medians (0.18 crossings/approach) was three times higher than highway with standard median width ($t_{100} = 3.8$, $P < 0.001$; see figure 4 for examples). The mean passage rate for the 24 elk approaching and crossing at Munds Canyon Bridge was 0.24 crossings/approach (±0.09), over three times higher than the adjacent highway with standard-width medians.

Effects of Traffic Volume on Elk Distribution

Our elk distribution analysis was based on 16,384 GPS fixes recorded within 600 m of the highway. Frequency distributions of mean probabilities showed a shift in distribution away from I-17 with increasing traffic volume (see Gagnon et al. [2011] for details). When comparing directly to SR 64 and SR 260 (Dodd et al. 2009a, 2010a) the most dramatic difference among highways occurred for low traffic (<100 vehicles/hour) in the 100 m zone immediately adjacent to roadway. Here, the probability of elk occurrence declined as a function of increasing AADT (Figure 5), with the probability of elk occurring adjacent to I-17 (0.12) being half that of SR 64 (0.24). Unlike SR 64, and to a lesser degree SR 260, elk did not exhibit a shift in distribution back to within 100 m of I-17 when traffic was at its lowest level.

Figure 5. Mean probability of elk occurring within 100 m of I-17, SR 64, and SR 260 at and their respective AADT when traffic volume was <100 vehicles/hour.
When considering elk distribution relative to traffic volume on I-17 sections with wide medians, the probability of elk occurring within 100 m of the highway at low traffic volume (<100 vehicles/hour) was 25% higher (0.15) than the probability associated with standard medians (0.12). The probabilities for elk occurring within 300 m of I-17 across all traffic volumes were consistently higher on highway sections with wide medians, an average of 17.5%, when compared to standard medians (see Gagnon et al. 2011 for details).

**Analysis of WVC and Relationship of EVC to Traffic Volume**

Agency personnel and project researchers recorded a total of 395 WVC from 2007 to 2010, accounting for 10 species (see Gagnon et al. (2011) for details on various species). Elk accounted for 80.0% of the WVC. Compared to the average surveyed bull:cow ratio for the elk population adjacent to I-17 (32.0 bulls : 100 cows), males were disproportionately overrepresented in EVC with a mean ratio of 74.5 bulls : 100 cows ($\chi^2 = 262.7$, df = 3, $P < 0.001$). The observed spatial distribution of EVC differed from a random distribution (Kolmogorov-Smirnov $d = -0.477$, $P < 0.001$), with several peak EVC zones apparent along the length of I-17 corresponding to the highway with the wide median below the Mogollon Rim and meadow complexes above the Mogollon Rim to the north.

The frequency of EVC by hour of the day along I-17 differed from expected ($\chi^2 = 148.7$, df = 15, $P < 0.001$), with the highest incidence of collisions occurring at 02:00 and 03:00. We found a strong inverse association between EVC and traffic volume ($r = -0.926$, $n = 16$, $P < 0.001$).

By day of the week, the frequency of EVC differed from expected ($\chi^2 = 15.2$, df = 6, $P < 0.019$), with the highest incidence of collisions occurring on Tuesdays when traffic volume was the lowest. We found a significant inverse association between EVC and traffic volume ($r = -0.833$, $n = 7$, $P < 0.020$; Figure 6).

**Influence of Riparian-Meadows on Elk Crossings and Collisions**

Of the I-17 segments above the Mogollon Rim ($n = 279$), the distance to the closest riparian-meadow habitat averaged 1534.6 m ($\pm 103.3$). We found that 136 (49.6%) segments were located within 1 km of riparian-meadow habitat adjacent to I-17, and 138 (50.4%) segments were farther than 1 km. Thus, the null model predicted that 50% of the I-17 elk crossings, weighted approaches and collisions with vehicles should have occurred at segments within 1 km of riparian-meadow habitat. However, the riparian-meadow proximity model actually predicted 61.4% of EVC and 64.2% of both elk crossings and weighted approaches (Table 1).

Our contingency table analyses indicated that proximity to riparian-meadow habitat had a significant influence on the locations of elk highway crossing, weighted approach, and EVC. The odds of an elk crossing occurring at a 0.16 km segment located within 1km of riparian-meadow habitat was three times that of occurring at a segments > 1km. The greater odds of weighted elk approaches occurring in proximity to riparian-meadow habitats were especially dramatic compared to approaches at segments away from meadows, (nearly 37 times higher; Table1). Elk-vehicle collisions were 70% more likely to occur at 0.16-km segments located in proximity to riparian-meadow habitat versus those segments more distant from such habitat.
<table>
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**Identification of Wildlife Passage Structure Sites**

We rated 75 1 km segments for their suitability and priority for potential passage structure locations and all but one section of the segments identified through our preliminary analysis (along the extremely wide median section) either had a passage structure proposed in the preliminary recommendations for the DCR or on an adjacent 1 km segment. The highest rated 1 km segment occurred along the stretch of I-17 with the extremely wide median just below the Mogollon Rim. Most of the higher scoring segments above the Mogollon Rim corresponded to riparian-meadow habitat complexes adjacent to I-17 (Figure 6). We recommended passage structures at each of these priority sites in the DCR. Once 1 km segments are identified through this process, fine-tuning of locations within each 1 km segment will occur using GPS movement and collision data at the 0.16 km scale, combined with a field evaluation of topography suitable for wildlife passage structures.

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**Figure 6.** Rating scores for aggregated 1 km segments along I-17 based on six rating criterion, including GPS movement data, with the mean score (15) indicated by the dashed line. Orange bars correspond to segments in which preliminary passage structures were recommended to the DCR planning team prior to completion of the elk movement study.
DISCUSSION

Theoretical models indicate that highways with traffic volumes above 10,000 AADT are impermeable barriers to most wildlife species (Seiler 2003, Iuell et al. 2003). Our study partially supports this assertion and shows that highways with high traffic volumes are a significant barrier to large, highly mobile species, such as elk. The threshold for elk, however, appears to be higher than 10,000 AADT. Elk regularly crossed nearby SR 260 at traffic volumes approaching these levels (Gagnon et al. 2007a) I-17 passes approximately 17,000 vehicles/day, which appears to severely hinder elk crossings, representing a nearly impermeable barrier for this motile species and indicating the possibility of a looming threshold. Elk along SR 260 crossed >11,000 times, whereas elk along I-17 crossed <1,000 times. Further, passage rates averaged only 0.09 crossings/approach on I-17 versus those on SR 260 with around half the traffic volume at 0.88 crossings/approach along this 2-lane roads prior to reconstruction (Dodd et al. 2007a).

Interestingly, we saw a substantial increase in elk highway crossings associated with a 3.2 km area that had an extremely wide median. We predict that this is a result of splitting a high-traffic volume highway into two smaller roads with approximately half the traffic volume. This is a significant result that can be tied to the importance of road configuration. Jaeger et al. (2006) modeled the effects of road “bundling” and suggested that “.....it is better to bundle the roads close together than to distribute them evenly across the landscape.” Higher incidence of elk-vehicle collisions in the wide median area indicates this may be the case for traffic related mortality, however, from a highway permeability standpoint, at least for elk, splitting the traffic into separate roads provides greater opportunity for them to cross the highway. This has implications for the success of wildlife crossing structures as well, given that elk distribution near I-17 was higher in areas with an extremely wide median, placement of wildlife crossings and fencing may allow wildlife greater opportunity to approach them as the road effect zone may be less than that of a bundled highway. In the case of I-17, these widened medians provide an opportunity through road configuration to potentially mitigate the effects of this highway on elk, and potentially other wildlife once wildlife passages are incorporated, however, it is important to note that these conclusions are limited to elk and until further research on other species is complete, bundling of new roads is the best option, given the generally irreversible direct and indirect habitat loss incurred by roads (Forman 2000, Jaeger et al. 2006).

The other crossing peak along I-17 was associated with a large bridge that has been in place since the reconstruction of the road more than 30 years ago. Apparently many of the local elk have learned to utilize this bridge to obtain resources on either side of I-17. This is not surprising given the success of wildlife crossings and their ability to minimize the influence of traffic on some wildlife species, such as elk (Gagnon et al. 2007b). Given the high incidence of wildlife vehicle collisions in areas adjacent to this bridge, fencing designed to funnel animals to wildlife crossings should further increase elk utilization of the bridge. Gagnon et al. (2006) compared the use of wildlife crossings prior to the installation of funnel fencing and found that only 11% of elk and deer that approached the underpasses crossed completely through, while others went either over both sets of lanes or under one lane and over the remaining lane, risking collision. In a related study, Dodd et al. (2007a) documented an 85% reduction in elk-vehicle collisions following the erection of funnel fencing relative to the preceding period that followed completion of the wildlife crossings structures, indicating that wildlife crossings without fencing will not significantly reduce the incidence of collisions. Further, Dodd et al. (2007d) identified a dramatic increase in passage rates following the completion of funnel fencing linking wildlife underpasses along the same section of road. These results provide insight into the effectiveness of tying fencing into existing structures.

Our attempt to validate the elk crossing model relative to proximity to riparian-meadow habitat, derived from SR 260 provided marginal results. The model predicted >60% of the crossings and collisions associated with I-17; however, the dynamics associate with high traffic volumes along this highway influenced the crossing and passage rates of elk that attempted to cross. Further validation and fine-tuning of this model is essential. Until then, given the risk of liability incurred by transportation agencies through WVC, we feel that mitigation for highways should be taken on a case-by-case basis as traffic volumes and habitat types play an important role in wildlife attempting to cross the highway.

Short-Term Solution – Retrofit of Existing Structures

ADOT recognized that the upgrade of I-17 would not occur for several years; thus, retrofitting existing structures provides an option for short-term resolution to the elk-vehicle collision problem (Dodd et al. 2010b, Gagnon et al. 2010a). In 2006, ADOT funded AGFD to conduct an elk movement pilot study that was intended to support development of an enhancement grant proposal for retrofit fencing, including providing information pertaining to the placement of fencing. In July 2007, with supporting data, AZGFD and ADOT jointly submitted a SAFETEA-LU highway enhancement grant application for the I-17 retrofit project. The application was approved for funding and is planned for implementation during 2011. This project focuses on a 9.6 km stretch that accounted for a disproportionate amount (28%) of all WVC while accounting for only 12% of the stretch of I-17 addressed in the long-term planning
efforts. This project will entail vertically extending the existing right-of-way fence to 2.4 m, which will funnel elk to the
two existing large bridges that are suitable for wildlife passage and create two dual-use structures at transportation
interchanges (Fox Ranch Road overpass and Schnebly Hill Road underpass), with the goal of reducing the incidence of
elk-vehicle collisions and promoting elk permeability across the highway.

Long-Term Solution – Incorporation of Wildlife Crossing Structures into the upgrade of I-17

ADOT is currently evaluating the long-range reconstruction of I-17 to address increased traffic volume and highway
safety issues. In 2006, ADOT began drafting an Environmental Assessment and developing a draft DCR that includes
recommendations of wildlife crossing locations for future assessment in the final DCR. Once approved, projects will be
reevaluated on a case by case basis as funding becomes available.

Using the cost figures identified by Huijser et al. (2007) and the I-17 WVC data for the mean annual incidence of vehicle
collisions with elk (79.0/year) and deer (14.0/year), we estimated that annual WVC cost a minimum of $1,466,561 for
elk and $117,432 for deer, totaling $1,583,933/year. Assuming that the results of these planned long-term mitigation
measures show reduction in collisions with large ungulates by a minimum of 85% as seen elsewhere (Woods 1990,
Clevenger et al. 2001, Dodd et al. 2007, Olsson and Widen 2008, Gagnon et al. 2010), we should realize a benefit of
$13,463,430 in the first ten years. Given that collisions with wildlife may increase with traffic volumes and that the
road may be widened from 4 lanes to 6-7 lanes; we anticipate that the benefits would likely exceed these values.

Whereas early passage structures were typically approached as single-species mitigation measures to address WVC
(Reed et al. 1975), the focus today is on preserving ecosystem connectivity and permeability benefiting multiple
species (Clevenger and Waltho 2000). Although this project is driven primarily by motorist safety and focuses on large
ungulates, the benefit to other wildlife along a highway of this magnitude will be substantial. Along SR 260, 70 km to
the southeast, Gagnon et al. (2011) documented the use of wildlife underpasses 21 species following its upgrade from
a 2-lane to a 4-lane divided highway. This project was also safety driven and focused on elk and deer, but provided
substantial benefit to many other wildlife species. Along I-17, the proposed wildlife crossing structures combined
with numerous large culverts linked with funnel-fencing will provide potential opportunity for smaller wildlife as well.

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approved by Rocky Mountain Elk Foundation and Arizona Elk Society.

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associated with highways and wildlife underpasses.

Norris Dodd retired from AZGFD after 29 years of service, and is currently a senior natural resource specialist for Aztec
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Scott Sprague has worked as a Research Biologist for AZGFD since 2002, focusing on wildlife-highway interactions. He
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Rob Nelson obtained his B. S. from Kansas State University with in wildlife biology. He has worked for AZGFD for 7
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Sue Boe received her B. S. and M. S. from the University of Minnesota - Duluth. She has worked for AZ Game and Fish Department since 1992 as GIS analyst on a wide variety of projects, both terrestrial and aquatic, including numerous wildlife-highway interaction projects. Sue and her husband live in Phoenix with their 2 dogs and three cats.

Ray Schweinsburg has been a research program supervisor with the department for 18 years. He received his Ph.D. from the University of Arizona and currently focuses on enhancing wildlife habitat connectivity throughout Arizona.

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ABSTRACT

An arterial connecting the rural and urban areas within King County, Washington runs through high-value wildlife habitat and a wildlife corridor protected by local regulations. A planned expansion of this arterial near the urban/rural interface would make safe wildlife movement through the area increasingly challenging. The construction schedule of this expansion presented an opportunity to establish habitat connectivity infrastructure prior to expanding the roadway. Project goals and objectives are to enhance motorist safety by reducing on-road wildlife encounters, create or reconnect viable wildlife corridors, improve safe wildlife movement across the roadway, improve habitat connectivity, and incorporate best available science.

After first establishing clear project goals and objectives, the team underwent a literature search to find a solution to our initial project challenge: where to place a wildlife crossing structure along the nearly 4-mile-long road corridor. Through the research, the team discovered that most available literature relates to wildlife crossing structures within rural or wilderness areas as opposed to more urban environments. Most crossings in the United States are designed to accommodate migrating wildlife, as opposed to localized populations with smaller ranges, or are placed in response to significant road kill data.

The team established a three-tiered system of site-screening criteria, which were tailored specifically for urbanizing landscapes. Criteria were developed to be site-independent (transferable from project to project), usable and meaningful to all road improvement projects for King County, and useful for rapid assessment in lieu of extensive wildlife crossing data.

Using the tiered criteria, the team examined the feasibility of placing a wildlife crossing structure along this arterial. Issues evaluated included wildlife species, habitat types present, habitat connectivity opportunities, property ownerships and future land use, vehicle safety and road engineering constraints, as well as recognition of topographic, cultural resource, and utility constraints. The tiered criteria system strongly indicated a preferred crossing location. The principle factors driving the selected location were habitat connectivity, existing and future land-use, and presence of natural and artificial guideways.

INTRODUCTION

Management of terrestrial wildlife in western Washington, including King County, is an important conservation objective. Rapidly expanding urban areas that interface with rural environments often have conflicts with wildlife. As existing roads are expanded and new roads are built to support suburban development, the challenge is to minimize the negative and unintended effects to wildlife, humans and the environment. Wildlife crossings are a tool for reconnecting vegetated areas that provide important habitat for terrestrial wildlife and support safe wildlife movement.

Over the past twenty years, North American research is increasingly available to assist agencies and the public in understanding how to reduce the impacts of roads on wildlife. This research has been directly applied to improve road...
safety and mitigation through wildlife habitat linkage analysis, development of effective wildlife and fish crossing structures, fencing, and land purchase or conservation easements, to protect important wildlife habitats (Ruediger 2001).

Many of the areas where wildlife crossings have been planned, installed, and studied are in rural areas – often along highways in open country. Often agencies have collected animal-vehicle collision (AVC) data to support crossing placement, and are not constrained by surrounding private land ownership. But if an agency decides to proactively install a wildlife crossing in an area that already has established roads and is within urban or sub-urban zoning, a large set of factors must be examined that are largely irrelevant to rural projects. Resources for information on wildlife crossing placement in urban or urbanizing areas is limited, outside of a few resources in and around key metropolitan areas along the west coast, most notably the Portland, OR metropolitan area (Anderson 2006) and Ventura County, CA (Cavallaro et al. 2005).

**PROJECT OVERVIEW / PROBLEM STATEMENT**

The placement of wildlife crossing structures is one of the most crucial points to assess during the design phase of a transportation construction project. Past projects and research recommends that the placement of passage structures should be near or within currently utilized wildlife corridors. These movement corridors often follow natural drainages and waterways, such as stream crossings, because they represent locations where multiple project and ecosystem needs converge and therefore offer an opportunity for synergistic solutions. In most of the literature, decisions about where to place crossing structures are based on empirical data. However, for time or budgetary reasons, sometimes it is not possible to gather monitoring data, and other methods must be used to determine where to place a crossing structure.

This paper presents an approach taken by King County staff to evaluate a road corridor at the urban/rural interface for placement of a wildlife crossing in lieu of monitoring data.

**The Project’s Goals and Objectives**

Numerous wildlife species use and move through the NE Novelty Hill Road corridor to meet their life history needs. This use and movement requires wildlife to cross NE Novelty Hill Road, and these crossings have consequences for safety of the animal as well as the motorized traveling public. With the planned widening of NE Novelty Hill Road and the concurrent growth-induced traffic increases through the corridor, it is anticipated that there will be an increase in conflicts and encounters between motorists and wildlife, including AVCs and wildlife-induced accidents.

To address these wildlife issues, King County Department of Transportation received a grant to evaluate potential areas for wildlife crossings, as well as identify a menu of structural and non-structural options for creating one or more viable and effective wildlife crossings within the NE Novelty Hill Road corridor, a busy road in a developing area. Design and construction of the wildlife crossing project was proposed to occur prior to or in conjunction with the already-planned road capacity improvements of the NE Novelty Hill Road Project (NHRP) in order to minimize community impacts and maximize infrastructure improvements in a timely fashion.

The purpose of the project was to facilitate the coexistence of wildlife with people in an area of unincorporated King County that has experienced a recent increase in residential and commercial development and is situated along the urban growth boundary. The project was intended to address the need to create conditions within the NE Novelty Hill Road corridor that allow wildlife to safely cross the NE Novelty Hill Road corridor. Safe crossing would reduce AVCs and other wildlife-related accidents, enhance motorist safety, and allow wildlife safer movement to meet life history and population needs.

**Goal 1:** Enhance motorist safety by reducing on-road wildlife encounters.

**Goal 2:** Create or reconnect viable wildlife corridors that (1) increase safe wildlife movement across roadways, (2) improve habitat connectivity, and (3) incorporate best available science.

Specific objectives pertaining to Goal 2 include: determining the target species, identifying the locations of their habitat, installing one or more structures to accommodate the size range of the target species, and installing or utilizing existing guideways to direct target species to the crossing structures.
**PROJECT AREA SETTING**

The project area is located within the Bear Creek Basin of King County, Washington (Figure 1). The area lies two miles north of Lake Sammamish (the second largest lake in King County) and covers approximately four miles of the NE Novelty Hill Road corridor. The eastern terminus of the project area is at the eastern edge of three urban planned developments (these UPDs are high-density, residential and commercial developments within an urban pocket surrounded by rural areas); the western terminus is located at the city limits of Redmond, population 54,000 and home of Microsoft Corporation and other large companies with ever-growing work forces.

Within the urban and rural settings that the NE Novelty Hill Road corridor traverses, there are a variety of land uses. Like most of the region, land use here has changed markedly in the past 150 years as development has increased and continues to occur. Historically, this corridor was predominately forested. Today land use is a mix of high-density residential, rural residential, private farmlands, mixed patches of forest, wetlands and aquatic features, grassy areas (non-native), and impervious surfaces. A rural agricultural area, the Snoqualmie Valley, lies to the east of the road corridor and UPDs, and to the west the landscape shifts to low-density residential land use consisting primarily of houses with large lawns, mixed with patches of trees and fenced pastures interspersed with wetlands and tributary streams. An 800-acre block of land, known as the Redmond Watershed Preserve, borders the north side of NE Novelty Hill Road and is managed as a nature preserve with a variety of natural habitats and extensive soft-surface trails. Beyond the project limits to the west, land use changes to higher-density urban residential within the City of Redmond.

**Roadway and Traffic Conditions**

NE Novelty Hill Road and existing roads in the vicinity are deficient in providing appropriate multi-modal transportation system capacity, traffic safety features, and meeting social and economic demands. Arterial roadways in the area have become increasingly congested and will be further burdened by projected transportation demands. Motorist safety is affected by a variety of factors including road configuration and setting, vehicle speeds, and the potential for interactions with non-stationary objects, such as wildlife and pedestrians. Portions of the existing NE Novelty Hill Road do not meet current King County road standards because of sight distances that are too short and curves that are too sharp. Traveling at the posted speed limit of 45 miles per hour (mph), motorists have a diminished ability to avoid collisions and collision severity is typically higher than at lower speeds. The combination of inadequate capacity and safety affects the social and economic climate of the community.

To address these problems, the NHRP will provide standard and regulatory-required roadway improvements in the corridor that will increase roadway capacity and improve safety for vehicular traffic, as well as other users, including bicyclists, pedestrians, and equestrians. Such improvements do not specifically address wildlife safety or mobility, in part due to the lack of collected data on wildlife populations, movement and AVCs in the area.

**Project Area Habitat**

The project area includes a wide variety of wildlife habitat, including temperate forest, open-water and emergent wetlands, streams and riparian areas, and urbanized areas that include landscaped areas, parks, and stormwater detention ponds.

The temperate forests of the Pacific Northwest are composed of deciduous and coniferous tree species and a thick undergrowth of shrubs and herbs. Approximately 3,850 acres of forest, ranging from young (5-30 years old) to mature second-growth (100+ years old), are present in the project area (King County 2008). These temperate forests support a wide variety of small and large mammals, which take advantage of the structural complexity, thermal heating/cooling, shelter, and food resources.

In addition to temperate forest habitats, approximately 560 acres of riparian and wetland habitat is present within the project area (King County 2008). Approximately 35 miles of potential in-stream habitat occurs in the project vicinity (King County 2008).

These identified habitat types can provide individual life-history and population requirements for various wildlife species in conjunction with designated open spaces and wildlife corridors, trails, and utility corridors of the human-constructed environment.
Figure 1: Wildlife Crossing Project Area.
**Project Area Terrestrial Wildlife**

Wildlife presence in the corridor area is typical of the suburban/rural fringe in Western Washington. Despite the intensive development in the region, parks, preserves, and other protected lands in the project area provide habitats that help many wildlife species persist. Based on numerous wildlife studies associated with local development, more than 100 wildlife species have been observed in the eastern portion of the corridor (Raedeke Associates, Inc. 2004).

While conducting literature reviews associated with the Redmond Ridge UPD, Raedeke Associates, Inc. (2004) documented the potential presence of 115 bird species, 46 mammal species, 6 species of reptiles, and 10 species of amphibians based on habitat features and past species accounts. The various field surveys throughout the project area confirmed the presence of 66 species of birds, 29 species of mammals, 2 species of reptiles, and 10 species of amphibians.

The wildlife species most relevant to this project are mammals, amphibians, and reptiles. Large and medium-sized mammals currently or potentially present in the Novelty Hill Road corridor include but are not limited to Columbian black-tailed deer (*Odocoileus hemionus columbianus*), cougar (*Puma concolor*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and American beaver (*Castor canadensis*).

Amphibians in the project area include northwestern salamander (*Ambystoma gracile*), long-toed salamander (*Ambystoma macrodactylum*), rough-skinned newt (*Taricha granulosa*), Pacific treefrog (*Pseudacris regilla*), and northern red-legged frog (*Rana aurora*). Reptiles present are the common garter snake (*Thamnophis sirtalis*) and the northwestern garter snake (*Thamnophis ordinoides*).

**KING COUNTY’S APPROACH TO SITING A WILDLIFE CROSSING (METHODS AND RESULTS)**

To effectively analyze the full project corridor for an appropriate and effective wildlife crossing location that meets the project goals and objectives, a three phase selection process based on wildlife crossing criteria was developed. The first phase selection criteria provides the tools for conducting an initial review of the project limits in an effort to select potential wildlife crossing areas within the transportation corridor for further consideration. In the second phase, those potential crossing areas that meet the criteria in first phase are further evaluated to determine how effective a wildlife crossing feature would be at each potential crossing location based on habitat connectivity, existing and future land use, vehicle safety, and construction/engineering feasibility. In the third phase, the top rated potential crossing area(s) is further evaluated for the most effective and practical structure type and alignment. This three phase selection process followed criteria developed through research of best practices in the industry (Cramer and Bissonette 2006, Hardy et al 2007, Huijser et al. 2007 and Iuell et al. 2003).

**First Phase: Initial Selection Criteria**

First phase criteria consisted of four mandatory criteria, as well as four additional criteria considered “highly desirable.” Locations along the corridor consisting of roadway segments, rather than pinpoints, were evaluated against the criteria. Locations that met criteria 1 through 4 of the following eight criteria were selected for further analysis; benefits of these locations were also noted relative to criteria 5 through 8:

1. Upland or riparian wildlife habitat is present.
2. Located within King County jurisdiction.
3. At a very cursory level of inspection, topography appears conducive to wildlife movement or poses no obvious barriers.
4. No known land-use restrictions are present to prevent the construction of a wildlife crossing feature.
5. Within close proximity and connected to an area known to have a relatively high proportion of wildlife habitat.
6. Publicly owned or other protected lands present (may include conservation easements).
7. Aquatic areas (such as stream, river, lake, marine shoreline, or other natural waterbody), wetlands, or Wildlife Habitat Conservation Areas (breeding or nesting sites of terrestrial species identified in the *King County Comprehensive Plan* and protected under the King County critical areas code) present.
8. Additional site-specific benefits to habitat connectivity are present (something on site that would augment or be augmented by the presence of a crossing structure).

After applying the first phase selection criteria to the NE Novelty Hill Road corridor, three locations met all of the first phase selection criteria and thus were identified as potential candidates for installation of wildlife crossing structure(s): Location #1, Wetland Complex; Location #2, Watershed Preserve; and Location #3, Stensland Creek (Figure 1). These locations are briefly described below and further analyzed as part of the second and third phases of the selection process.
criteria. The remainder of the corridor did not meet selection criteria 1 through 4. Typically, other areas faced one or more of the following problems:

- Wildlife habitat present in the vicinity was isolated, fragmented, or non-existent;
- Locations were outside King County jurisdiction; or
- Locations had other land-use related limitations, such as residential properties on both sides of the road.

**Location 1 – Wetland Complex**

The first location, the Wetland Complex location, is located on the east end of the road corridor. The areas immediately north and south of NE Novelty Hill Road at this location are part of an expansive wetland complex and second growth coniferous forests, as well as the rapidly urbanizing, high density UPDs. Two wetlands are connected on either side of NE Novelty Hill Road by an existing 24-inch corrugated metal culvert under the road. The King County Code-designated Wildlife Habitat Network (WHN) crosses NE Novelty Hill Road at these wetlands.

**Location 2 – Watershed Preserve**

The second location, the Watershed Preserve location, is located centrally in the project area, in the vicinity of the Williams Gas Pipeline that crosses NE Novelty Hill Road at the southeast corner of the Redmond Watershed Preserve, between 218th Avenue NE and Cedar Park Crescent Road NE. Immediately to the north of NE Novelty Hill Road at this location is the Redmond Watershed Preserve, 800 acres of second growth coniferous forest, streams, ponds, and riparian habitat. South of NE Novelty Hill Road, land use is single family homes on parcels ranging from approximately one acre in the rural-zoned area to approximately 0.1 acres in the UPDs. Patches of second growth coniferous forest also exist south of the road, along either side of the cleared, mowed pipeline corridor.

**Location 3 – Stensland Creek**

The third location to be analyzed, the Stensland Creek location, is located near the western end of the corridor, in the vicinity of the future intersection of NE Novelty Hill Road and 195th Avenue NE (to be created under the NHRP), near the City of Redmond limits and the Bear Creek Valley.

The area immediately to the north of NE Novelty Hill Road is a mixture of agricultural lands and single family residences. A future north-south roadway, 195th Ave NE, will connect to NE Novelty Hill Road from the south in this area. A wildlife crossing will be constructed in 2011 beneath 195th Avenue NE to facilitate east-west wildlife movements. The Bear Creek corridor lays approximately one-half-mile to the west of the Stensland Creek location and is used by wildlife as a corridor (King County 2009).

**Second Phase: Selection Criteria**

This second phase focused on the value of a crossing relative to habitat connectivity, land cover and ownership as a surrogate for the longevity of protected wildlife habitat, and the benefits to vehicle safety at each of the three potential wildlife crossing locations. As part of the second phase selection criteria, topographic and some engineering criteria were also examined with respect to feasibility considerations, including potential site constraints, such as topography, utilities, and cultural resources that may make a potential crossing location less suitable for a crossing structure compared with other potential locations.

The criteria include a point system that was used to objectively rank the locations and identify the best candidate for a large-animal wildlife crossing (a large-animal crossing was considered as the limiting factor because of the larger size requirement; the assumption being smaller animals could use a larger crossing, but the converse is not true). For each criterion, the three crossings were rated using a system of 0, 1, 3, or 5 points. An award of 5 points indicates that a crossing location met the criteria, an award of 3 points indicates that the crossing location met a portion of the criteria (as specifically stated in the individual questions), and an award of 0 or 1 indicates that the crossing location does not meet the specific criteria.

Additionally, not all of the criteria were valued at 5 points. Those criteria deemed most important to the success of the wildlife crossing (meeting project goals and objectives) were worth 5 points. Those criteria considered to be of moderate importance were given 3 points. And those criteria with an assumed smaller contribution to project success were assigned 1 point. This point system is intended to be simple yet comprehensive. By using a system of 1, 3, or 5 points, the top candidate location should be separated from the others by more than just 1 or 2 points. In fact, if one
location does not clearly stand out as the preferred alternative, more than one of the locations may be recommended for the third phase.

The second phase criteria are contained below within Tables 1 and 2. Table 1 evaluates potential benefits of each location, while Table 2 evaluates potential constraints.

**Table 1. Habitat Connectivity, Land Cover and Ownership, and Vehicle Safety Table.**

<table>
<thead>
<tr>
<th>Habitat Connectivity</th>
<th>Wetland Complex</th>
<th>Watershed Preserve</th>
<th>Stensland Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are there sightings documented by WDFW, established animal trails, or sign within the project area or 150 ft. on either side and identifiable from the right-of-way? (Yes, animal trails or sign = 5 pts; Yes, sightings = 3 pts; No = 0 pts)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2. Are aquatic areas, wetlands, and/or riparian areas present within the project area or within a 300 ft. radius on either side? (Yes, both sides of road = 5 pts; Yes, one side of road = 3 pts; No = 0 pts)</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>3. Are aquatic areas, wetlands, and/or riparian areas that are not included in the question above located within 0.5 miles of the road and not connectively severed from the road by development? (Yes = 1 pt; No = 0 pts)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4. Is one of the following true, based on the “Landscape Forest Value” data in the GIS shapefile &quot;forest_conn&quot;? (No = 0 pts) • High-value forest on both sides of the road (Yes = 5 pts) • High-value forest on one side of the road and moderate- or low-value forest on the other (Yes = 3 pts) • Moderate- or low-value forest on both sides of road (Yes = 1 pts)</td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>5. Does the crossing location/area fall within the WHN? (Yes = 5 pts; No = 0 pts)</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. Does the crossing location/area fall within protected habitat that connects to the WHN? (Yes = 3 pts; No = 0 pts)</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>7. How wide is the native vegetated habitat corridor at this location (as measured at the next feature past the built environment)? If vegetation is different on the two sides of the road, use narrowest width. (&lt;100 feet wide = 0 pt; 100-300 feet wide = 1 pt; 300-600 feet = 3 pt; &gt;600 feet = 5 pt)</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>8. Is habitat contiguous and no narrower than 300 ft beyond the road crossing for at least 0.5 miles (habitat for this exercise includes pasture and undeveloped utility rights-of-way)? (Yes, both sides of road = 5 pts; Yes, one side of road = 3 pts; No = 0 pts)</td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

**Subtotal** 31 18 10
<table>
<thead>
<tr>
<th>Land Cover &amp; Ownership</th>
<th>Wetland Complex</th>
<th>Watershed Preserve</th>
<th>Stensland Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is adjacent land publicly owned (open space, natural area, nature preserve) or within a conservation easement? (Yes, both sides of road = 5 pts; Yes, one side of road = 3 pts; No = 0 pts)</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2. Are there topographic features (steep slope, valley walls, ridges) or vegetated line that would naturally guide animals to this location? (Yes = 3 pts; No = 0 pts)</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>
| 3. Are there barriers to wildlife movement at the crossing location?  
  - No natural barriers (e.g., cliffs) = 1 pt  
  - Man-made barriers (fencing, walls, ecology blocks) that could be removed = 1 pt | 1               | 1                  | 1               |
| 4. If points were awarded in the Habitat Connectivity section questions 7 or 8, what is the zoning in these areas of upland habitat? (1 DU per 10 acres = 3 pts; 1 DU per 5 acres = 1 pts; Less than 1 DU per 5 acres = 0 pts) | 0               | 1                  | 1               |
| **Subtotal**                                               | **4**           | **8**              | **5**           |

<table>
<thead>
<tr>
<th>Vehicle Safety</th>
<th>Wetland Complex</th>
<th>Watershed Preserve</th>
<th>Stensland Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is this an area with animal-vehicle collisions as documented by WDFW, Sheriff, or similar source? (No = 0 pts; Yes, one collision = 3 pts; Yes, two or more collisions = 5 pts)</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2. Based on the existing road configuration, will placement of wildlife crossing feature(s) likely mitigate one or more current safety deficiencies at this location? Safety deficiencies include, but are not limited to, the following examples, which all reduce drivers’ response time to on-coming hazards: short sight distance, sharp curves, high speed limits (40 mph or greater), traffic regularly exceeding posted speed limit, vegetation along the road shoulder restricting visibility of roadway. (Yes = 5 pts; No = 0 pts)</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>3. Are there or will there be vegetated medians or other features that could attract wildlife within the road alignment (by providing cover or forage habitat)? (Yes = 0 pts; No = 3 pts)</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>6</strong></td>
<td><strong>6</strong></td>
<td><strong>5</strong></td>
</tr>
</tbody>
</table>

i Or similar reputable source.
ii High Forest Value was assigned to those forested areas as designated by 2002 University of Washington land cover data meeting any one of the following criteria:
  - Patches of contiguous forest ≥ 40 ha (100 ac) in size and with ≥ 90 m (300 ft) external buffer. These patches would include corridors ≥ 180 m (600 ft) wide.
  - Corridors ≥ 90 m (300 ft) wide that connect to at least one patch as described above.
  - Those stepping stone patches (see “moderate forest value”) that connect to at least one core interior forest patch.

iii Moderate Forest Value was assigned to forested areas meeting any one of the following criteria:
  - Patches of forest ≥ 4 ha (10 ac) and < 40 ha (100 ac) in size and with ≥ 90 m (300 ft) external buffer.
  - Corridors ≥ 90 m (300 ft) wide that connect to at least one patch as described above but do not connect to High-value forest.

iv A legal agreement between a landowner and a qualified conservation organization or a government agency that permanently limits land uses in order to protect conservation values. Typically, development is permanently limited to little (such as a single residence for the landowner) or none.
Table 2. Topographic and Cultural Feasibility Considerations.

<table>
<thead>
<tr>
<th>Feasibility Considerations</th>
<th>Wetland Complex</th>
<th>Watershed Preserve</th>
<th>Stensland Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the topography at the site of the potential wildlife crossing such that it would facilitate the construction of either an underpass (because the road is raised on fill that could potentially be excavated) or an overpass (because there are high slopes on both sides of the roadway)? (Yes = 3 pts; No = 0 pts)</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2. Is it anticipated that property would need to be acquired (through easement or in-fee purchase) in order to construct a wildlife crossing in this location? (Yes = 0 pts; No = 5 pts)</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Underground utilities exist at the potential crossing location (Yes = 0 pts); OR No underground utilities exist at the potential crossing location, but aboveground utilities (including traffic lights) exist (Yes = 1 pt); OR No utilities exist in this location that would encumber development of this property (Yes = 5 pts).</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Is there a roadway intersection (signalized or non-signalized) within 500 ft of the potential crossing location? (Yes = 0 pts; No = 3 pts)</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Is the width of the improved right-of-way:</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>• Less than or equal to 44-feet = 3 pts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Between 44 and 66-feet = 1 pt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Equal to or greater than 66-feet = 0 pts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Are there cultural or archaeological resources identified in the screening process within a 500-ft radius of the crossing location? (Yes = 0 pts; No = 5 pts)</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total       14   1     6

Each of the potential wildlife crossing locations identified in first phase was evaluated using the second phase of selection criteria. This second phase analysis evaluated each of the potential wildlife crossing locations relative to its ability to meet the project goals, as well as screened each site for implementation feasibility. The analysis resulted in a comparison of the locations based on the site benefits and constraints. Individual criteria worth points between 0 and 5 were evaluated; categories of criteria were analyzed to determine a site’s strengths and weaknesses; and a sum of the points was used to rank the sites (see Table 3).

Table 3. Summary of Second Phase: Selection Criteria.

<table>
<thead>
<tr>
<th>Summary</th>
<th>Wetland Complex</th>
<th>Watershed Preserve</th>
<th>Stensland Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat Connectivity</td>
<td>31</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Land Cover &amp; Ownership</td>
<td>4</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Vehicle Safety</td>
<td>6</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Feasibility Considerations</td>
<td>14</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>33</td>
<td>26</td>
</tr>
</tbody>
</table>
The Wetland Complex location ranked highest in with a total score of 55, which is 66 percent of the total points. Its habitat score averaged about twice as high as the other two locations because of the presence of quality wildlife habitat features and habitat connectivity, such as the network of connected wetlands and the codified WHN. Its preliminary feasibility score was at least twice that of the other two locations because: it is the only location where additional right-of-way or easements would not need to be purchased, it is the only location where cultural or archaeological resources were not identified within 500-feet of the location, and there are no roadway intersections within 500-feet of the location. These existing characteristics rank the Wetland Complex location with the highest feasibility score. Because the Wetland Complex location ranked highest, it was further evaluated in the third phase. No further analysis of the Watershed Preserve and Stensland Creek areas were completed.

Final Phase: Crossing Criteria and Cost Evaluation

As a result of the first and second phases, the Wetland Complex location was identified as the preferred area. The final phase of this process, which would be standard in any wildlife crossing project, help to: (1) determine the best alignment within the preferred location, (2) determine the type of crossing, and (3) analyze costs associated with the selected crossing.

Two alignments at the Wetland Complex location were selected for evaluation of designing and constructing a wildlife crossing structure: (1) the hydraulic connection point of the two wetlands (herein referred to as the wetland crossing), and (2) the intersection between the road prism and the Puget Sound Energy high transmission line (herein referred to as the powerline crossing). King County evaluated the options of a wildlife underpass and a wildlife overpass.

Wildlife Underpass (below-grade structure): For each alignment, King County considered underpass options that had a combination of minimal and optimal dimensions. King County evaluated the wildlife underpass structure using three widths: 40 feet, 60 feet, and 100 feet. For each width, different structure opening heights were also considered, from 8 feet (minimal) to 12 feet (optimal).

Wildlife Overpass (above-grade structure): Because of foreseeable impacts associated with the installation of footings used to span the road at the wetland crossing, a wildlife overpass was only evaluated for the powerline crossing. At the powerline crossing, King County evaluated the wildlife overpass structure using three widths, including 40 feet, 60 feet, and 100 feet.

The following alignment evaluation criteria were used to further screen the Wetland Complex location for an appropriate crossing structure:

- Potential impacts to critical areas – The wildlife crossing should minimize adverse impacts to critical areas such as wetlands and their buffers.
- Potential impacts to wildlife habitat, such as tree removal – The wildlife crossing project should minimize impact to the forest that is providing habitat for wildlife targeted by the crossing, thereby maximizing the success of the crossing.
- Potential risk associated with future roadway alignment improvements – The wildlife crossing project should be designed with flexibility for accommodating the future road improvements.
- Potential impacts to existing utilities – Above ground and below ground utilities can result in significant constraints to the structure configuration or add high costs to the project (re-location of utilities).
- Existing ground water and surface water – Ground water elevations and proximity to surface water may eliminate the use of a particular crossing structure type. For example, shallow ground water may inundate a wildlife underpass, saturating or flooding it during wet seasons; or due to the close proximity of a wetland open water feature cannot facilitate the approach to a wildlife overpass.
- Existing road configuration – Vertical dips and rises, horizontal curves, crosswalks, trails, and intersections (signalized, roundabout, and stop sign controlled) can limit or enhance the use of wildlife crossing structures. For example, sight distance requirements place restrictions on the distance a wildlife overpass can be from intersections or curves in the roadway.
After going through these criteria, King County determined that it was infeasible to construct a successful wildlife underpass or an overpass at the wetland crossing alignment for reasons including the inability for the crossing to meet minimum suggested size requirements as well as wetland buffer impacts.

The alignment evaluation screening criteria revealed that the best wildlife crossing option for the Wetland Complex was a wildlife overpass at the powerline crossing. The wildlife overpass option at the powerline crossing has minimal to no impacts to protected critical areas, will result in minimal habitat removal (southern approach will be in the powerline right-of-way, which is already disturbed), will accommodate future planned road improvements, minimizes potential impacts and relocation needs associated with utilities, and eliminates ground water concerns.

The project team prepared two cost estimates for a wildlife crossing overpass structure to establish an anticipated range of construction costs (Table 4). Estimates are presented in 2009 dollars.

<table>
<thead>
<tr>
<th>Work Category</th>
<th>40’ Span</th>
<th>60’ Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW</td>
<td>$96,000</td>
<td>$96,000</td>
</tr>
<tr>
<td>Construction:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structures</td>
<td>$2,534,000</td>
<td>$3,168,000</td>
</tr>
<tr>
<td>Roadway/Civil</td>
<td>$625,000</td>
<td>$800,000</td>
</tr>
<tr>
<td>Utilities</td>
<td>$40,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Construction Management</td>
<td>$800,000</td>
<td>$1,002,000</td>
</tr>
<tr>
<td>Total</td>
<td>$4,095,000</td>
<td>$5,106,000</td>
</tr>
</tbody>
</table>

CONCLUSIONS: SPECIAL CONSIDERATIONS AT THE URBAN/RURAL INTERFACE

Our team began our siting project with what seemed a logical question: Where are the animals crossing the road? Which led to the next question: Where is the habitat located? In hindsight, we might have started with a different set of questions to limit our scope. If an agency wants to identify the single best location to place a wildlife crossing regardless of all other issues, it is appropriate to begin with the questions of actual wildlife crossings and habitat, in addition to areas with repeat animal-vehicle collisions. But in the real world of practical application, there are a great many feasibility issues to contend with, and it may make more sense to begin by removing entire areas from consideration based upon these restrictions.

Urban and urbanizing areas are more often than not composed of many relatively small parcels in private ownership, as opposed to large tracts of publicly owned property. Questions to ask when siting a wildlife crossing in an area with mostly private ownership include:

- Does the project budget include in-fee purchase of private parcels? Demolition of existing structures?
- Does potential exist for landowners to be willing sellers?
- Will landowners in lots adjacent to crossing structures oppose potential increased presence of wildlife?

Very frequently, outside the road rights-of-way, land is held in private ownership, and unless landowners are willing to lose potentially large portions of their land, finding space to build the bases of overpasses could be difficult to impossible.

The locations with the most space to support a crossing structure may lead to a dead-end of habitat, so it is important to look at the larger landscape when planning a location. And similarly, it is beneficial to thoroughly research the likely future build-out of the area under consideration. Even though a large swath of undeveloped forest land may be present on either side of the roadway during the planning process, if the area is subplatted and developed at some future time, ask whether any habitat will remain that would continue to make the location attractive to wildlife.

Most areas with any sort of residential zoning will have utilities in place underground, above ground, or both. It is a good idea to bring in an engineer at the beginning of the planning process to find out what underground utilities are in place, as well as to get feedback on the cost and feasibility of relocating them if necessary. For example, when considering raising a road for an underpass or placing an overpass structure over an existing alignment, the clearance needed for the existing power lines in combination with any road grade increase or new elevated structure would have to be
considered. If power lines are present overhead, increases in road grade would have to be built in consideration of them. And if a vegetated corridor is present at a potential crossing location, it might be a utility corridor – buried gas pipelines, for example, may have restrictions about how much excavation could occur nearby.

Trails and trail users may play a role in planning a crossing. Trails may already be established and will need to be accounted for in terms of how these pathways will be reconstructed (if necessary) and how trail users may potentially impact a wildlife crossing. For example, if there is a chance that pedestrians, equestrians, or mountain bike riders will wish to test out a wildlife overpass, precautions may need to be built in to the design to discourage use by humans.

Fencing is a tool for guiding the animals to the crossing structures. In an area with multiple private properties, obtaining permission to install fence could be challenging. Because wildlife crossings in conjunction with wildlife fencing can provide an 80 percent reduction in ungulate-vehicle collisions (Clevenger et. al, 2001), fencing is a crucial step in the functional success of a crossing structure.

If not already a part of the planning process, a public forum presenting initial ideas and requesting feedback from the residents of the area is recommended. Make sure the support of the public is in place if there is any question of how political pressure could influence the outcome of a project. And keep good records of numbers of attendees, how many were in favor, and solicit feedback in writing.

If it is anticipated that private property will need to be used, either for part of the crossing structure or for fencing, garnering public support will be crucial. Education, both pre- and post-construction, will be a key element in gaining the support of the community.

ACKNOWLEDGEMENTS

Financial support for this project came in part from the Federal Highway Administration Transportation Enhancement Program.

Ronda Strauch, former Supervising Environmental Engineer, and Manuela Winters, former Senior Environmental Engineer, were instrumental in obtaining the design grant for this project.

BIOGRAPHICAL SKETCHES

Howard Haemmerle, Acting Supervising Ecologist, has been involved with research on ecosystem recovery processes in the Pacific Northwest and Central Rocky Mountains for more than 25 years; the last 21 with King County. He has a Bachelor of Science degree in Biology from the University of Puget Sound and a Masters from the University of Wyoming. He is currently a supervising ecologist with King County’s Department of Transportation, RSD, Engineering Services Section where he manages their Mitigation Monitoring Program and supervises the sections technical staff providing scientific and technical guidance to the department.

Toni Hartje, Environmental Engineer, graduated from the University of Washington, Program on the Environment in 2002 with a Bachelor’s degree in Environmental Studies, with specific emphasis on the conservation and ecology and engineering principles. She has seven years professional experience in the environmental and engineering field, primarily in the area of regulatory compliance and permitting for projects involving property acquisition, remediation, and transportation infrastructure improvements.

Janel London, Senior Environmental Engineer, graduated from the University of Washington in 1994 with a Bachelor’s of Science in Civil Engineering, with emphasis on environmental and water resource issues. Janel has over 17 years’ experience in the transportation field with focus on regulatory compliance, environmental innovation and integration, and policy and organizational improvement.

Todd Martin, Wildlife Biologist, graduated from the Evergreen State College in 1994 with a Bachelor’s degree in Environmental Studies with specific emphasis on the flora and fauna of the Pacific Northwest. Todd has worked 3 ½ years with King County and has spent much of his time researching, advising, and contributing design ideas for wildlife crossings and connectivity issues. Prior to coming to King County, he focused on endangered and threatened species research, studies, and conservation.

Jennifer Vanderhoof, Senior Ecologist, graduated in 1992 with a Bachelor’s of Science in Wildlife Biology from Kansas State University and has been with King County Department of Natural Resources and Parks for over 11 years. At the County, she focuses primarily on biodiversity issues, terrestrial ecology, climate change, and the intersection of science and policy.
REFERENCES


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King County. 2009. NE Novelty Hill Road Project Critical Areas Report-Wildlife Areas. King County Department of Transportation, Seattle, WA.

