A Regional Ecosystem Framework for Terrestrial and Aquatic Wildlife along the I-70 Mountain Corridor in Colorado

An Eco-Logical Field Test

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Executive Summary

Balancing transportation demands with wildlife movement needs is an ongoing challenge for departments of transportation across the country and throughout the world. In Colorado, the I-70 Mountain Corridor (the Corridor) is generally recognized as a major barrier to movement for a number of wildlife species. For over a decade, the Colorado Department of Transportation (CDOT) has been analyzing traffic congestion, safety, environmental and stakeholder concerns along the Corridor, and in 2011, the Federal Highway Administration and the Colorado Department of Transportation (CDOT) released a Final Programmatic Environmental Impact Statement and Record of Decision, the first step in long-term planning for potential improvements to the Corridor from Glenwood Springs to Denver. This planning process provided 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.

The I-70 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 and project delivery. The ultimate objective of the I-70 Eco-Logical 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) that will help improve permeability for wildlife, reduce AVC rates, and lessen impacts to protected status species. 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.

The I-70 Regional Ecosystem Framework is designed to achieve on the ground results using a two-pronged approach based on comprehensive data synthesis and analysis, and clearly defined stakeholder processes for increasing transparency and accountability in the planning, design and implementation of wildlife permeability measures. Connectivity goals for the I-70 Mountain Corridor include providing routes for seasonal migrations, allowing wildlife whose home ranges are bisected to access habitat on both sides of the road, and providing dispersal opportunities to individuals. Original and existing information was collected relating to terrestrial and aquatic wildlife species along the Corridor. This information derived from a variety of sources including camera traps that collected data on wildlife activity at

existing bridges and culverts, wildlife habitat data, animal-vehicle collision data, wildlife observations recorded online by the driving public, and an extensive field survey of existing bridges and culverts, which provided an assessment of the current permeability of the Corridor for select species. The compiled data were used to develop a systematic process for validating and refining the priority connectivity zones originally delineated in 2004. As a result, 17 Linkage Interference Zones (LIZs-2011), covering approximately 51 miles, were identified in the 2011 analysis (Table 2), compared to 13 zones encompassing 65 miles in 2004. In addition to defining terrestrial connectivity zones, the I-70 Eco-Logical Project also identified road-stream crossings important for fish passage. Priority road-crossing locations were identified as streams with target species present and an absence of intentional barriers along the stream segment.

All information was analyzed and summarized to provide CDOT with preliminary recommendations for considering terrestrial and aquatic wildlife movement needs during planning, design, construction, and operations and maintenance. Connectivity recommendations were developed with the goal of providing the best mitigation in the best places and working towards a consistent vision of connectivity across the Corridor. Recommendations for improving permeability for terrestrial wildlife are focused in the LIZs-2011, although additional measures may be warranted at other locations throughout the Corridor. These mitigation recommendations provide an initial guide for incorporating connectivity needs into Corridor projects that will be further developed during Tier 2 planning processes. Ultimately, achieving permeability within a LIZ will require multiple safe passage opportunities to maintain and restore landscape permeability.

While in some cases new wildlife crossing structures are needed to accommodate the target wildlife in an area, in others, an existing structure may be modified to function for wildlife passage. Wherever feasible, recommendations for improving the existing roadway infrastructure to promote wildlife passage are provided. These include retrofitting existing bridges and culverts, maintenance activities, such as clearing vegetation, or the adding guide fencing to an existing bridge or culvert. These ‘early enhancement opportunities’ are low-cost measures that can be conducted outside of projects and have the potential to improve the functionality of an existing structure for passage by some or all of the target species in an area. By identifying where early enhancement opportunities are feasible along the Corridor, small connectivity improvements can move forward without having to wait for major infrastructure projects to commence. Consequently, early enhancement opportunities are excellent mechanisms for building success early through small projects and demonstrating efficient use of transportation dollars to reduce AVCs and improve landscape permeability for wildlife. Other locations also suitable for wildlife enhancements may also be present outside of the defined LIZs-2011, and these should also be considered as opportunities arise to promote corridor-wide permeability.

Table 1. LIZs-2011 in the I-70 Mountain Corridor. Primary and secondary target species derived from the LIZ analysis process and are meant to guide initial planning efforts; project planning and design may need to consider additional target species at a site. For complete descriptions and recommendations, refer to *I-70 Connectivity Recommendations*.

LIZ NAME	Mileposts Range	Primary Target Species	Secondary Target Species
Dotsero	130.9 – 131.3	Elk, Mule Deer	Elk, Mule Deer
Wolcott West	151.2 – 154.1	Canada Lynx, Elk, Mule Deer	Canada Lynx, Elk, Mule Deer
Wolcott	155.3 – 156.3	Elk, Mule Deer	Black Bear, Canada Lynx, Moose, Mountain Lion, Northern Leopard Frog
Wolcott East	157.1 – 159.6	Elk, Mule Deer	Black Bear, Canada Lynx, Moose, Mountain Lion, Northern Leopard Frog, River Otter
Dowds Junction	169.4 – 172.8	Canada Lynx, Elk, Mule Deer	Black Bear, Moose, Mountain Lion, Northern Leopard Frog, River Otter
Vail (East)	176.8 – 180.1	Canada Lynx	Black Bear, Boreal Toad, Elk, Moose, Mountain Lion, Northern Leopard Frog
Gore Creek	180.9 – 182.1	Canada Lynx	Black Bear, Elk, Moose, Mountain Lion, Mule Deer, Northern Leopard Frog, River Otter
West Vail Pass	182.9 – 188.1	Canada Lynx	Elk, Moose, Mountain Lion, Mule Deer, Northern Leopard Frog
East Vail Pass	191.8 – 194.2	Canada Lynx, Elk, Mule Deer	Elk, Moose, Mountain Lion, Mule Deer, Northern Leopard Frog
Wheeler Junction	195.2 – 195.8	Canada Lynx	Moose, Northern Leopard Frog, River Otter
Laskey Gulch	207.3 – 209.0	Canada Lynx, Elk	Black Bear, Moose, Mule Deer, Northern Leopard Frog, River Otter
Hamilton Gulch	211.6 – 212.4	Canada Lynx	Black Bear, Moose, Northern Leopard Frog
Bakerville	216.4 – 227.1	Canada Lynx	Bighorn Sheep, Black Bear, Boreal Toad, Elk, Mountain Lion, Northern Leopard Frog
Empire Junction	231.6 – 232.9	Canada Lynx	Bighorn Sheep, Black Bear, Elk, Mule Deer, Northern Leopard Frog
Clear Creek Junction	243.0 – 244.9	Elk, Mule Deer	Bighorn Sheep, Canada Lynx, Mountain Lion, Preble's Jumping Mouse
Beaver Brook	245.5 – 250.2	Elk, Mule Deer	Black Bear, Canada Lynx, Mountain Lion, Northern Leopard Frog, Preble's Jumping Mouse
Mt Vernon Creek	252.8 – 257.6	Elk, Mule Deer	Black Bear, Canada Lynx, Mountain Lion, Preble's Jumping Mouse

In addition to site-specific or LIZ-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. The guidance includes practices for siting and designing pipes, culverts and bridges to facilitate wildlife passage, as well as retrofitting existing structures and construction guidelines for minimizing impacts to wildlife and habitat connectivity. These guidelines inform Corridor-wide planning and feed into projects as Tier 2 planning processes commence. All connectivity recommendations and guidance are easily accessible via the 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, available on the I-70 Mountain Corridor CSS website (http://i70mtncorridorcss.com/).

While data and analysis are critical elements in informed, ecosystem-based decision-making, so too are the stakeholder processes that provide a framework for integrative planning. The I-70 Eco-Logical Project built upon an inter-organizational committee tasked with addressing wildlife connectivity concerns in the Corridor. The agencies and stakeholders engaged in the ALIVE Committee informed the general project approach, tasks and outcomes. In this way, the I-70 Eco-Logical Project advanced the development of mechanisms for integrating connectivity concerns into transportation planning for the I-70 Mountain Corridor, as outlined in the ALIVE Memorandum of Understanding. These mechanisms are designed to facilitate early incorporation of terrestrial and aquatic connectivity in each life cycle phase of the planning process, improve predictability in the environmental review process, and avoid delays in project development and delivery.

To support the objectives of ecosystem-based planning and collaboration, 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. The ALIVE Implementation Matrix provides lends structure and guidance in addressing connectivity concerns as projects on the Corridor move into Tier 2 planning. 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 that are needed to improve, protect, or restore permeability for wildlife and important habitat components.

Finally, performance measures were developed as a means of measuring success towards the overall goals of increased streamlining and predictability in environmental review and enhanced connectivity for terrestrial and aquatic wildlife. Specific performance measures have been identified at both the Corridor level and the project level. These performance measures ask targeted questions and provide milestones for gauging progress.

Specifically, dedicated wildlife monitoring programs are needed to evaluate whether connectivity measures are performing as intended. Monitoring offers project-specific benefits that can help prevent the need for costly retrofits in the future, while helping to fine-tune mitigation measures through adaptive management. Monitoring of new mitigation strategies and experimental designs provides crucial information as CDOT determines their effectiveness and assesses whether such strategies may be replicated elsewhere. Furthermore, the evidence provided by monitoring efforts on the effectiveness of mitigation measures is an important tool in maintaining agency and public support for wildlife crossings.

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. The I-70 Eco-Logical Project has equipped CDOT with strategic guidance that can be used from the outset of project planning to integrate strategies for minimizing impacts to wildlife movement and even restoring lost connections. 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.

CHAPTER 1

Introduction

The I-70 Mountain Corridor (the Corridor), defined as the section of Interstate 70 between Denver and Glenwood Springs, traverses variable mountainous terrain including steep grades, canyons, and large tracts of forest and sagebrush (Map 1). The Corridor passes through five different biomes covering an elevation range from 5,700' west of Golden, to a high point of over 11,000' at the Eisenhower/Johnson Tunnels, where the road crosses under the Continental Divide, and back down to 6,100' at Dotsero. The primary impacts to wildlife as a result of the highway include direct habitat loss and fragmentation; barriers to wildlife movement and increased mortality from animal-vehicle collisions; intensified impacts on adjacent habitats (i.e., traffic noise and light in the road-effect zone, and the use of deicer and traction sand in winter, etc.); and the indirect effects of increased population growth and land use changes on wildlife habitat (Colorado Department of Transportation 2011).

This section of interstate is generally recognized as a major barrier to movement for a number of wildlife species (U.S.D.A .Forest Service 2002). The Draft I-70 Programmatic Environmental Impact Statement (PEIS) released in 2005, notes that "the primary issue affecting wildlife in the Corridor is the interference of I-70 with wildlife movement and animal-vehicle collisions. Barriers to wildlife movement include structural, operational, and behavioral impediments to wildlife trying to cross I-70" (CDOT 2004, 3.2-5). The Final PEIS explains, "[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 2011, 3.2-1).

Across the globe transportation infrastructure is a significant cause of habitat fragmentation, resulting in animal-vehicle collisions, altered wildlife movements, and reduced rates of reproduction and survival (Reed et al.1996, Forman et al. 2003, Trombulak and Frissell 2000, Evink 2002, Huijser 2006). The sheer number of highway miles in the United States often necessitates that wildlife must cross roads to fulfill daily and seasonal movement needs, access their full home range, or disperse from one area to another. The impacts are pervasive – a 16-foot wide road removes approximately two acres of habitat per mile of road, and it is further estimated that the impacts of the road (noise and edge habitat) extend at least 600 meters beyond the road footprint on either side of a roadway (Forman and Deblinger 2000). Dodd et al (2007*a*) reported a 50% decrease in crossing rates for deer and elk when Highway 260 in Arizona was widened from two lanes to four. In Colorado, habitat fragmentation due to transportation infrastructure has been identified as a major threat to native wildlife, in particular, large and mid-sized mammals (Colorado Division of Wildlife 2006).

The fragmentation effect of a road is influenced by a number of variables such as the roadway footprint, traffic speeds, traffic volumes and median and shoulder barriers (Clevenger and Kociolek 2006). Animal-vehicle collision (AVC) rates are dependent on both traffic volume and the number of animals crossing the roadway (Roof and Woodling 1996; Barnum 2000), and rates along this 130-mile segment vary accordingly. Stretches of roadway with high AVC rates represent locations where animals are unsuccessfully attempting to cross a roadway, whereas areas with low AVC rates may be areas where animals are able to successfully cross the roadway; locations where animals are not attempting to cross the roadway at all, either because it is not a preferable crossing location, or because the roadway is too much of a barrier; or the actual collision rates may be – and generally are – underreported, particularly when there is no property damage. While roads with medium traffic volumes often have the highest AVC rates because more animals are attempting passage (Clevenger and Huijser 2011), several studies have demonstrated that because of barrier effect, high volume roads have the greatest impacts to wildlife populations (Brody and Pelton 1989, Rondinini and Doncaster 2002, Chruszez et al 2003).

A synthesis of multiple North American research studies demonstrates 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, although a number of species are susceptible to road mortality or barrier effects at lower traffic volumes (Charry and Jones 2009). A highly traveled interstate highway, traffic counts all along this 130-mile stretch of I-70 are well above the conservative 10,000 AADT threshold, ranging from 11,000 AADT at the western end of the segment to 66,000 at the eastern end, with temporal variations based on season and time of day (CDOT Traffic Data 2011). Between 2000 and 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 2011, ES-4). Unless specific mitigation measures are instituted to improve the permeability of the interstate for wildlife through the construction of wildlife crossings, the barrier effect of this roadway will be complete.

Balancing transportation needs with wildlife movement needs is an ongoing challenge for departments of transportation (DOTs) across the country and throughout the world. 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 values that are not addressed until late in the planning process can often slow down transportation projects and add unnecessary costs, resulting in strained relationships between DOTs and stakeholders, as well as highway designs that fail to address environmental, cultural, and social values.

Furthermore, because highway projects are typically designed and implemented on a project-by-project basis often without a landscape-scale perspective, mitigation has been limited to project boundaries as opposed to locations with the greatest potential benefits. For these reasons, the current transportation planning process does not always ensure that the right conservation mitigation happens in the right place.

As Colorado's population continues to grow, CDOT struggles to accommodate expanding communities, improve safety and reduce traffic congestion. I-70 is a prime example as the only east-west interstate across Colorado. I-70 is a critical arterial for the communities located along its length as well as for Denver and cities along the Front Range, serving local, regional and interstate commerce, tourism, and recreation. The Corridor provides access to major ski resorts and two of the most visited National Forests in the United States. Interstate trucking combined with summer and winter recreational travel leads to major traffic delays, particularly during peak travel times on weekends and holidays. Commuter traffic leads to weekday delays in the western and, increasingly, eastern portions of the Corridor. This congestion is predicted to worsen over the next 20-50 years, with corresponding negative impacts to the economies and communities that depend upon this transportation corridor (CDOT 2011).

1.1. I-70 Mountain Corridor Planning Processes

Recognizing these challenges and growing demands on the transportation network, CDOT and the Federal Highway Administration (FHWA) initiated planning processes in 2000 to develop various alternatives to make improvements in the Corridor and analyze the impacts of each proposed option. These efforts resulted in a Draft PEIS in 2004, followed by a Revised Draft PEIS in 2010. In June 2011, FHWA signed a Record of Decision approving the Preferred Alternative, as described in the Final PEIS, and informing all future projects in the Corridor such that they are consistent with the Corridor vision. The Preferred Alternative provides a framework for reducing congestion, improving safety and protecting stakeholder-identified values, including permeability for wildlife. The Preferred Alternative is a multi-modal solution that offers a range of potential improvements as a combination of enhanced public transportation, including an Advanced Guideway System; driver education and behavior modification strategies; and highway improvements (CDOT 2011). The Decision provides a framework for implementing projects in the Corridor as funding allows and marks the onset of Tier 2 planning processes.

Notably, in undertaking the Revised PEIS, CDOT launched a Collaborative Effort, engaging 27 agencies and organizations representing a variety of interests (I-70 Collaborative Effort 2011). Guided by a professional facilitator, the Collaborative Effort was tasked with identifying a consensus recommendation to be adopted as the Preferred Alternative for the I-70 Mountain Corridor. As projects move forward in the Corridor, CDOT and FHWA have committed to long-term stakeholder engagement via the Collaborative Effort, which will continue meeting at least every two years as the Preferred Alternative is implemented, bringing ongoing accountability to the Corridor vision.

Complementing the Collaborative Effort, CDOT simultaneously commenced a Context Sensitive Solutions (CSS) process to guide transportation decision-making and design in a manner that reflects stakeholder-identified values in the Corridor. CSS principles have been used by states across the nation to facilitate appropriate, cost-effective and successful avoidance and mitigation measures to compensate for the negative impacts of transportation infrastructure (Center for Transportation and the Environment 2006). The CSS convened the full range of stakeholders to identify core values and guide decision-making that considers the total context of social, economic, archeological and environmental considerations that may be affected by a transportation project. The CSS process is intended to guide all future planning processes in the I-70 Mountain Corridor, incorporating stakeholder-identified goals 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 2011).

1.1.1. 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 the development of mitigation strategies as a part of the I-70 PEIS (Solomon 2007). 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 U.S.D.A. 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).

The goals of the ALIVE committee were fourfold (CDOT 2004):

- Designate key wildlife habitat including Canada lynx habitat;
- Identify and characterize Linkage Interference Zones (LIZs, i.e., roadway segments important for wildlife movement);
- Analyze specific conflict areas for wildlife roadway crossings within the linkage interference zones;
- Provide recommendations for mitigating conflicts through wildlife crossings and other techniques including fencing and land conservation strategies.

The ALIVE committee reviewed existing data, information on historic movement patterns, and expert opinion to identify thirteen LIZs where wildlife movement routes, dispersal corridors or other movement pathways are bisected by the interstate between Denver and Glenwood Springs. The LIZs form the basis for prioritizing mitigation efforts in areas of greatest importance for wildlife movement, and for each LIZ, the ALIVE committee proposed preliminary mitigation recommendations, including wildlife crossings and land protection (CDOT 2004). These recommendations are general strategies and were not designed specific to any of the alternatives in the PEIS. Meeting notes documenting the thought processes leading to the identification and delineation of these LIZs are available (Solomon 2007), but the evaluation process for delineating LIZs was neither standardized nor consistentent.

The final objective of the ALIVE program was to develop cooperative agreements between CDOT and the regulatory and resource agencies. To advance this goal, and to facilitate collaboration in the development of effective mitigation measures to minimize transportation impacts on wildlife, a Memorandum of Understanding (MOU) was drafted in 2006 and signed in 2008. The intent of the MOU is to help CDOT and FHWA fulfill their Section 7 consultation requirements under the Endangered Species Act, reduce the demands of future consultation requirements, and ensure that mitigation and land management strategies are implemented by the responsible jurisdiction and in the best locations regardless of where the actual transportation projects are located, thereby ensuring the greatest benefit to wildlife and wildlife habitats at a landscape scale. The ALIVE committee notes that "this strategy proceeds from the premise that restoration of impacted habitats and preservation of critical habitats is more likely to meet stated mitigation goals than local creation of habitat, and that restoration and preservation require a watershed or regional perspective for successful implementation" (Solomon 2007).

1.1.2. 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 consistency in considering aquatic connectivity throughout the Corridor (CDOT 2011).

1.2. Mitigating Transportation Impacts on Wildlife: A Primer

As transportation infrastructure expands, the challenge is to minimize the negative and unintended effects to humans, wildlife, and ecological systems (Hardy et al 2007). Selecting appropriate wildlife mitigation measures for a given highway segment is a complex process constrained by topography, competing land uses and cost. In addition, what works for one species may not work for others. Each situation must be considered individually, taking into account the particular species that make use of that environment, their life history traits and population dynamics (Kintsch and Cramer 2011).

Increasingly, wildlife crossings are being used as a tool to mitigate the negative impacts of transportation-related infrastructure and traffic on wildlife populations and to provide wildlife with safe passageways under or over a roadway. Even where new roads are not being built, a growing body of scientific research underscores the importance of these wildlife crossings in helping to restore habitat connectivity for wildlife across existing roadways (Clevenger et al 2002*a*; Evink 2002). Wildlife crossing structures – including overpasses and underpasses, in conjunction with wildlife fencing - have been shown to restore and maintain landscape connectivity, as well as reduce animal-vehicle collisions (Bank et al 2002; Clevenger 2002*a*; Knapp 2005; Dodd et al 2007*a*). Species preferences for crossing structures are contingent on a number of factors relating to location, size, and design (Hardy et al 2007), and are based on the biology of the species as well as environmental factors that affect how a species perceives potential passageways (Kintsch and Cramer 2011).

Barnum (2003) demonstrated that wildlife do not cross roads randomly, but select crossing locations based on access to cover, forage, prey or other landscape and habitat features. Locating crossing structures within preferred crossing areas is essential for ensuring the success of these structures (Foster and Humphrey 1995, Clevenger and Wierzchowski 2006). A combination of animal-vehicle collision data, GIS-based analyses, game trail mapping, wildlife movement patterns and habitat maps, and expert information can all be used to help identify crossing areas (Clevenger et al 2002*b*, Meese et al 2009). Further site-specific assessments and species-specific field studies (e.g., Scheick and Jones 1999, Clevenger et al 2002*a*, Dodd et al 2007*b*) and engineering assessments are needed to pinpoint the best and most cost-effective locations for new wildlife crossing structures, although landscape and roadway features, such as suitable habitat, road cuts and shoulder barriers, can also be appraised to help determine structure locations (Barnum et al 2007).

Designing effective mitigation solutions is further complicated by the need to consider the movements and passage preferences of not just one, but multiple target species present in a given area (Foster and Humphrey 1995, Barnum 2003, Clevenger and Waltho 2005, Clevenger and Huijser 2011). Because individual species may perceive barriers in the landscape differently (Lima and Zollner 1996) and different species prefer different crossing structure characteristics (Mata et al 2005, Cramer et al 2011*b*), a multi-species approach requires balancing these various considerations during the planning and design phases of a project.

Regardless of the mitigation type, it is apparent, as DOTs nationwide consider how to better address transportation needs in the context of protecting and restoring healthy wildlife populations and ecosystem processes, that integrative planning must commence at the earliest stages to project visioning and budgeting to sufficiently capture these needs. Incorporating connectivity considerations at the outset of a project ensures that mitigation efforts are fully integrated into project designs, reducing costs and preventing delays in project delivery.

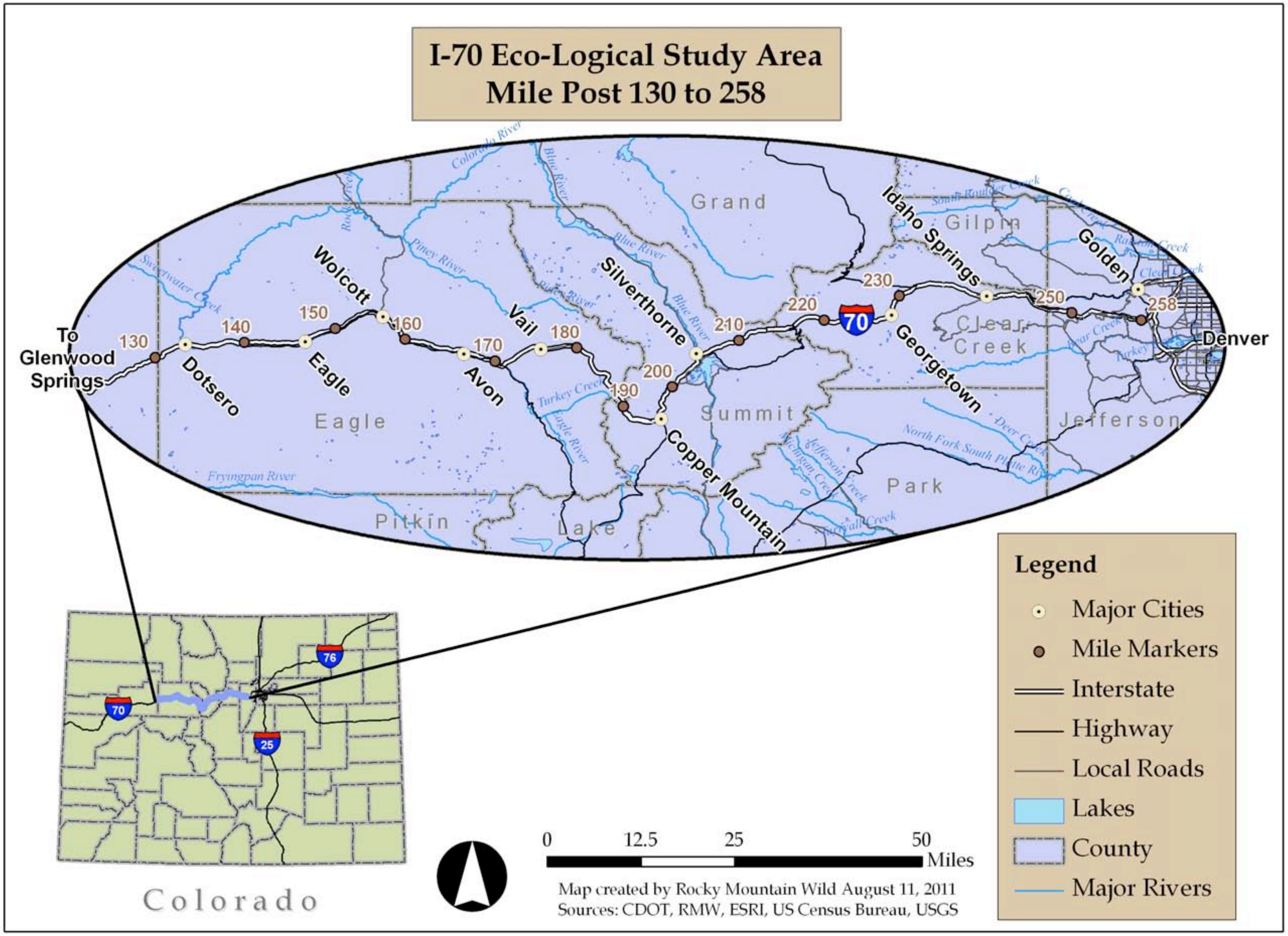
1.3. The Eco-Logical Framework: I-70 Field Test

FHWA describes the foundation for ecosystem-based mitigation in a report entitled, *Eco-Logical – an Ecosystem Approach to Developing Infrastructure Projects* (Brown 2006). Ecosystem-based mitigation is described as "the process of restoring, creating, enhancing, and preserving habitat and other ecosystem features in conjunction with or in advance of projects in areas where environmental needs and the potential environmental contributions have been determined to be the greatest". Building on the premise that transportation infrastructure can be developed in ways that are more ecologically sensitive, FHWA is promoting the idea that mitigation should be done in the best place ecologically; mitigation need not be constrained to the boundaries of a transportation project if greater benefits could be realized elsewhere. Interagency collaboration and partnerships are identified as key elements of an Eco-Logical approach, and mechanisms to support partnership and collaboration should be incorporated from the earliest stages of planning and visioning. This process-oriented approach is designed to bring agency and stakeholder concerns into view during the earliest stages of transportation planning to maximize mitigation effectiveness, remove uncertainty in environmental review, and avoid delays in project development and delivery. The Eco-Logical approach supports greater flexibility in addressing ecosystem concerns while meeting regulatory requirements in a more timely and cost-effective manner.

To test the ideas put forth in the Eco-Logical report and to produce real-world examples of a Regional Ecosystem Framework, FHWA initiated a grant program in 2007. Fifteen grants, totaling $1.4 million, were awarded to teams across the country (Bacher-Gresock and Schwarzer 2009). These field tests are instrumental in demonstrating the concepts of an ecosystem approach. The Interstate 70 (I-70) Regional Ecosystem Framework was awarded one of these grants. Project tasks commenced in January 2009 and were completed in September 2011.

The progress that CDOT had already made towards long-term planning for potential improvements along the I-70 Mountain Corridor offered a unique opportunity to apply the Eco-Logical framework to support the preservation and restoration of key wildlife linkages across Colorado's high country. As the existing roadway situation of I-70 currently presents an extensive impediment to wildlife movement, highway improvements offer excellent opportunities for enhancing conditions for wildlife passage under or over I-70 and lessen the overall barrier effect of the interstate, even where the highway footprint may increase.

The ultimate objective of the I-70 Eco-Logical 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) that will help restore habitat connectivity for wildlife, reduce AVC rates, and lessen impacts to protected status species (Map 1). 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. The strength of the Regional Ecosystem Framework, as applied in the I-70 Mountain Corridor, lies in the expansion of an integrative planning process that is supported by a comprehensive connectivity assessment of the Corridor. This framework provides CDOT and Corridor stakeholders with the structure for collaborative, informed decision making necessary for ensuring timely and effective project delivery.



Map 1. I-70 Eco-Logical Project study area.

CHAPTER 2

Informing a Regional Ecosystem Framework: Data and Analysis

The I-70 Regional Ecosystem Framework is a two-pronged approach based in comprehensive data synthesis and analysis, and clearly defined stakeholder processes (Section 3) designed to increase transparency and accountability in the planning, design and implementation of wildlife permeability measures. While these parallel components are discussed separately here, it is important to note that they occurred concurrently such that stakeholders informed data collection and analysis efforts which, in turn, informed information needs and priorities for integrative planning and stakeholder collaboration.

This section describes the methods and outcomes of an extensive effort to compile existing data sources on wildlife movement patterns; compile new, complementary data and information; validate and revise the LIZs originally delineated in 2004 and identify road-stream crossings important for fish passage; and develop preliminary mitigation recommendations for restoring connectivity for wildlife across the interstate. As a part of these efforts, the project team compiled original and existing information on terrestrial and aquatic wildlife from a variety of sources including an extensive field survey to assess the current permeability of I-70 for select species; camera trap data on wildlife activity at existing bridges and culverts; wildlife habitat and species presence data; animal-vehicle collision data; and data obtained through a website where the public reported wildlife sightings. This data compilation was then used to develop a systematic and transparent process for updating and validating the 13 LIZs identified in 2004, and develop an analogous process for identifying road-stream crossings that are important for fish passage. This information was summarized to guide the development of preliminary mitigation recommendations for enhancing conditions for terrestrial and aquatic connectivity.

As a result, CDOT and its agency partners are now equipped to integrate connectivity recommendations from the outset of project planning to facilitate environmental streamlining and project implementation. The mitigation recommendations provide an initial guide for incorporating connectivity needs into Corridor projects that will be further developed during Tier 2 planning processes. Where possible, these mitigation recommendations highlight opportunities to improve existing structures for wildlife passage as well as identifying needs for new crossing structures to accommodate target species movements

2.1. Data Compilation and Collection

2.1.1. Species and Habitat Data Compilation

Species with connectivity concerns in the I-70 Mountain Corridor include terrestrial species whose movement paths intersect the interstate and native fish species that occur in streams bisected by the interstate. Terrestrial target species were identified as species with threatened and endangered, sensitive or other special status, or any other species with a safety or habitat fragmentation concern in the context of the I-70 Mountain Corridor. Aquatic target species included threatened and endangered, sensitive and other special status species as well as any native species with a barrier or habitat fragmentation concern. A list of all terrestrial and aquatic species is available in *Appendix A*.

Terrestrial species are categorized according to their Species Movement Guild, a road-ecology classification for designing functional wildlife crossing structures (Table 1; Kintsch and Cramer, 2011). These Guilds categorize wildlife based on their body size, modes of locomotion and preferred crossing structure characteristics – preferences that are largely based on predator avoidance behaviors and the need for continuous habitat conditions through a crossing structure. The classification system facilitates an understanding of the influential features that render a structure functional or non-functional for different types of wildlife, and allows transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement from the perspective of groups of species. This understanding facilitates strategic mitigation that carefully consider the behavior

Table 1. Species Movement Guilds (Kintsch and Cramer, 2011).

Movement Guild	Typical Species of That Guild
Low Mobility Small Fauna	Invertebrates, frogs, toads, some salamanders
Moderate Mobility Small Fauna	Squirrels, raccoons, hares, weasels
Adaptive High Mobility Fauna	Black bear, bobcat, coyote, lynx
High Openness, High Mobility Carnivores	Grizzly bear, mountain lion, wolf
Adaptive Ungulates	Deer, moose, mountain goat
Very High Openness Fauna	Elk, bighorn sheep, pronghorn antelope
Arboreal Fauna	Flying squirrels, some bats
Aerial Fauna	Songbirds, raptors, bats

and preferences of each target species and allows generalization across species in a common Guild. Refer to *Appendix B* for a complete description of each of the Species Movement Guilds.

Wildlife habitat data were compiled from CDOW's Natural Diversity Information (NDIS 2010) Source database and other sources for each terrestrial target species for which spatial data was available: bighorn sheep, black bear, boreal toad, Canada lynx, elk, moose, mountain lion, mule deer, northern leopard frog, Preble's meadow jumping mouse and river otter. Habitat data layers compiled for this project include winter and summer ranges, migration corridors, concentration areas, occupied habitat and other species-specific habitat data, and species-specific linkage models (Southern Rockies Ecosystem Project 2008).

AVC data were also compiled for the analysis. The Colorado State Patrol's (CSP) database provides a summary of reported wildlife-related accidents across the Corridor; additional roadkill records are maintained by CDOW for particular species of interest, including Canada lynx, mountain lion, and black bear. AVCs are generally recognized as being severely underreported as well as unevenly reported over time and geographies (Romin and Bissonette 1996, Hesse 2006, Sielecki 2010). Further, AVC rates do not reflect impacts to a wildlife population, which may be more severe for a small population (e.g., lynx) than a large population (e.g., deer). Regardless, concentrations in AVCs can help define problematic stretches of roadway and, as such, were included as one of multiple layers in the analysis to redefine connectivity zones in the Corridor.

The I-70 Mountain Corridor traverses through three watersheds – the Eagle River, Blue River and Clear Creek watersheds, and touches on two additional watersheds, the South Platte River (near the eastern end of the study area) and the Colorado River watershed at the western end. Aquatic target species identified for this project include any threatened and endangered, sensitive, and other special status native fish found within these watersheds as well as any native species presenting a barrier or habitat fragmentation concern in the context of the I-70 Mountain Corridor, as determined by biologists at CDOW and USFWS (*Appendix A*).

CDOW is the authoritative source for all aquatic data in the state of Colorado (H. Vermillion, CDOW, personal communication, March 10, 2011). Data requested from the agency was used to determine whether target species presence in a stream segment was confirmed, absent or unknown (some structures had no available data). At some locations, natural barriers are present or man-made barriers have been installed to protect existing native cutthroat trout populations from invasion by non-natives and/or contain the spread of 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. Stream segments with the potential to restore native cutthroat trout were identified as potential barrier locations even though there is currently no barrier present.

2.1.2. Roadway Inventory

A number of roadway features influence the permeability of I-70 for different wildlife species. Influential features include the number of traffic and auxiliary lanes, interchanges and frontage roads; traffic speeds; underpasses at select locations that may function as wildlife crossings; median and shoulder barriers; the presence of a vegetated median; proximity of suitable habitat; terrain features (including natural cliffs and road cuts); and elevation differences between opposing traffic lanes.

Existing span bridges on Vail Pass are regularly used by wildlife (this study; Barnum 2003) and a box culvert at Dowds Junction near Vail was specifically installed to accommodate migratory deer. Other existing bridges and culverts may also function as occasional or regular wildlife passages. Meanwhile, other roadway features, such as median and shoulder barriers may impede wildlife movement for small and large animals alike. Continuous, concrete barriers are though to have the greatest impacts, prevent crossings and impeding visibility, and the combination of median and shoulder barriers simply compounds these effects (Clevenger and Kociolek 2006). On a high volume road such as I-70 these features reinforce the barrier effect of the entire highway.

The intent of the roadway inventory for the I-70 Eco-Logical Project was to compile information about all of the existing culverts and bridges along I-70 as well as other infrastructure and habitat features that may facilitate or inhibit wildlife movement.[1] Within the 130-mile 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 potential crossing locations without an existing structure, such as fill slopes at natural drainages that may serve to funnel animals towards the roadway 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.

Each site was assigned a unique identification number and its location was recorded using a hand-held GPS unit. For each location, two worksheets were filled out to record information on the site's terrestrial and road segment characteristics. For sites with perennial water flow, an additional worksheet was filled out to document the aquatic characteristics of the site as they relate to fish passage. All measurements of structural dimensions were made using a 100-meter open reel measuring tape or, for longer distances, a Nikon Forestry 550 Hypsometer Rangefinder. Large areas such as the imprint of a fill slope were measured by pacing.

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[1] For the complete roadway inventory, refer to the Access database accompanying this report. Inventory data is also available on the CSS websites map viewer at http://i70mtncorridorcss.com

Some measurements, such as length of culverts, were unobtainable in the field. These measurements were estimated later using the ruler tool in Google Earth. Photo documentation of each inventoried location is available by accessing the inventory database. *Appendix C* describes each of the fields of information collected for the roadway inventory.

The roadway inventory catalogued existing structures under I-70 and provided an initial field assessment of the extent to which these structures may function as passages for terrestrial or aquatic wildlife. Road-stream crossings were rated: 'resembles natural channel', 'adequate', 'inadequate', or 'indeterminate'. Terrestrial structures were not explicitly rated in the field for their ability to pass terrestrial wildlife, however the information collected in the inventory was expressly used to determine functionality for different types of wildlife and to develop enhancement or replacement recommendations. This assessment was further validated through camera monitoring at select locations (Section 2.1.3).

Median and/or shoulder barriers are present along many segments of the I-70 Mountain Corridor. Barrier types include guardrails, concrete jersey barriers, and cable rail. Information on the presence of median and shoulder barriers, including barrier type and height, was compiled at each inventory location. Median barriers can trap or slow wildlife attempting to cross a road, thereby increasing the likelihood of an animal-vehicle collision (Clevenger and Kociolek 2006). The visual impact of a median or shoulder barrier can also preclude animals from attempting to cross (Barnum 2003). More detailed mapping and analysis of barriers along the Corridor would facilitate a greater understanding of how these types of infrastructure affect the movement ability of different types of wildlife.

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. a 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 at the other end of the cliff. 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. A detailed description of the criteria used to map wildlife fencing and other roadway barriers can be found in *Appendix C*.

The roadway inventory was completed during the summer of 2009. Since that time, there have been some changes to the roadway infrastructure. Notably, additional wildlife fencing has been constructed in the western portions of the study area and new concrete shoulders barrier have been installed along the eastbound side of West Vail Pass. While the GPS inventory of wildlife fencing has been updated to reflect these additions, other changes to the roadway infrastructure are not reflected in the roadway inventory database.

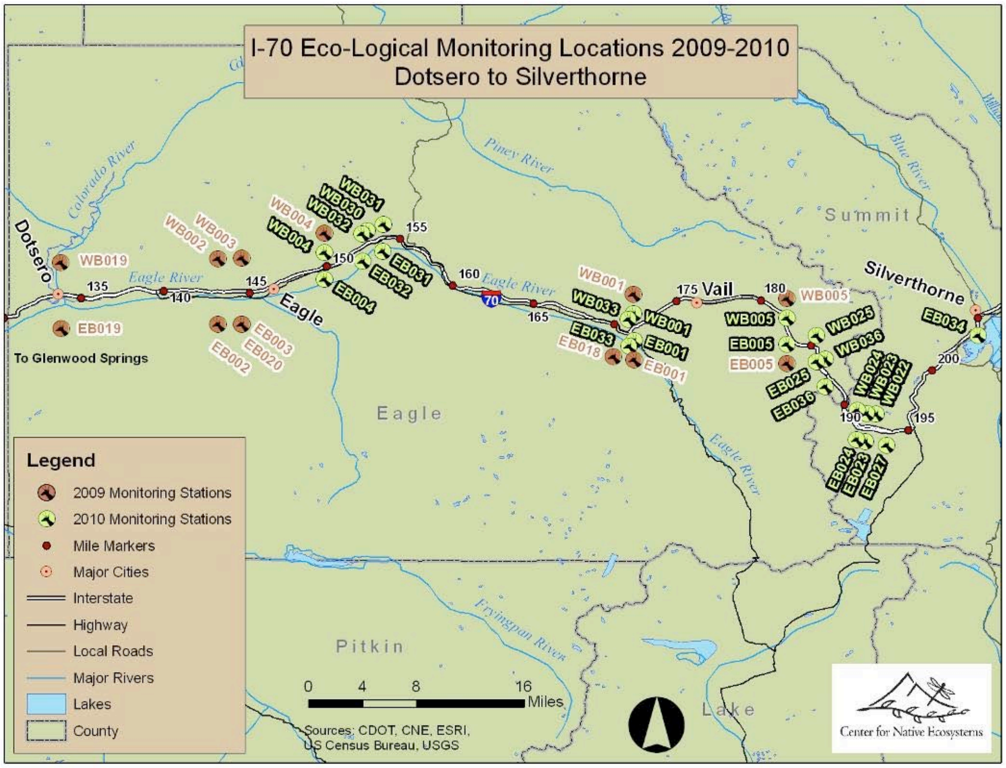
2.1.3. Camera Monitoring

Camera monitoring was conducted to collect baseline information on wildlife activity 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 33 stations at 19 milepost locations. In the 2010 field season, cameras were set up at 38 monitoring stations at 24 milepost locations, targeting sites preliminarily identified as important for wildlife movement (Maps 2 & 3). Monitoring locations targeted existing bridges and culverts that may function for some wildlife as well as potential crossing locations, such as fill slopes blocking natural drainages, where there are no suitable crossing structures. One camera was stolen in 2009, three in 2010. Monitoring data was used to detect patterns in wildlife activity that may not be captured via other data sources, such as the habitat data layers or AVC rates. No monitoring was conducted to track measures of aquatic connectivity as a part of this study.

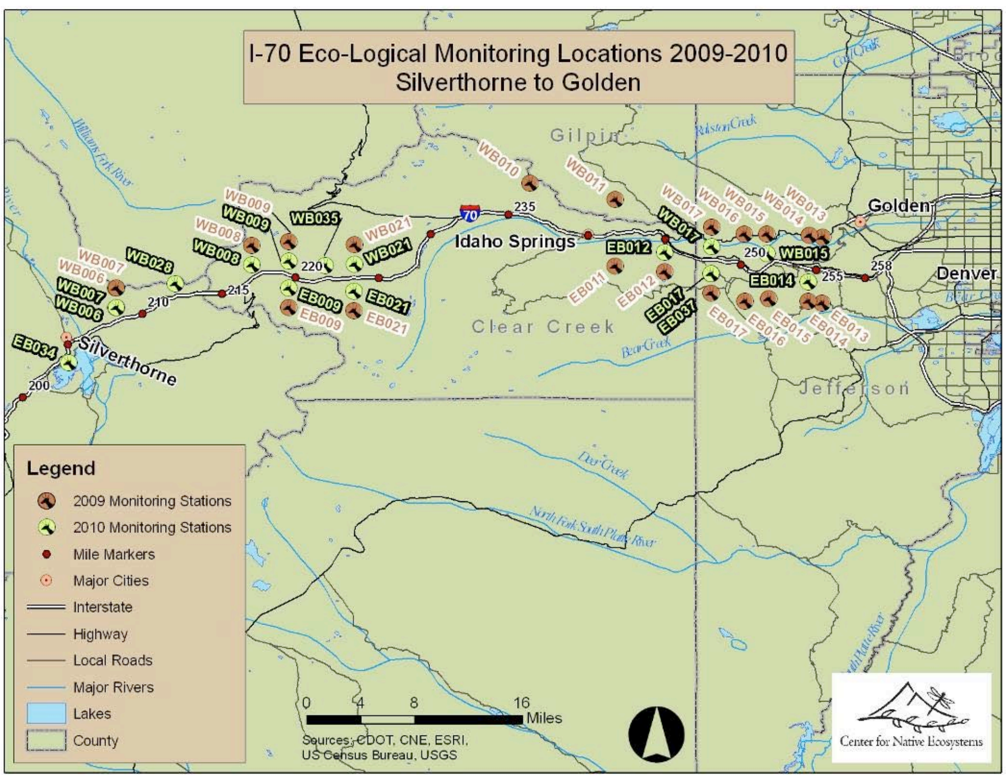
Monitoring sites in 2009 were selected based on the previously identified LIZs-2004. Stations that fell outside of these zones were located at structures with potential for wildlife use or other locations, such as natural drainages, that may funnel wildlife activity towards the roadway. In 2010 monitoring activities were focused within segments preliminarily identified through the LIZ-2011 analysis process (Section 2.2.1). Recognizing that camera monitoring does not fully capture all wildlife activity at a site (Bonaker 2008), an effort was made to expand monitoring activities in the second year of the project to include track beds using the existing substrate at the site. Due to insufficient substrate that did not sufficiently register track imprints, 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 track data was collected when researchers were in the field to maintain the cameras every four to six weeks.

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 humans and domestic animals such as goats, cattle, dogs and house cats. This monitoring data gave us insight into the type of species using various structure types in addition to information on the time of day and season certain species are most active.

The Dowds Junction culvert (MP 171.8) near Vail offers an interesting case study. This concrete box culvert was specifically installed as a wildlife crossing to accommodate seasonal deer migrations. The dimensions of this structure (~10x10x100’) are considered sufficient, though not ideal, for passing mule deer, particularly large populations, such as those that pass through here during the spring and fall migrations. These dimensions are not considered sufficient for



Map 2. Camera monitoring locations in 2009 and 2010 in the western portion of the study area, from Dotsero to Silverthorne.



Map 3. Camera monitoring locations in 2009 and 2010 in the eastern portion of the study area, from Silverthorne to Golden.

regular use by elk, a species that prefers larger and more open crossing structures (Cramer et al 2011*b*). Camera monitoring at this location validated these species-specific passage requirements. A number of mule deer were detected passing through the structure during the spring and fall seasons (monitoring was not conducted in the winter months). While individual elk do appear to occasionally use this box culvert, camera monitoring also documented elk repelling from the structure. These results suggest that there has been some local adaptation to the structure, which was constructed in the 1970's. However, it may still present a barrier to elk and other species that require larger and more open passageways. Black bear, fox and raccoon were also recorded at this site.

On East Vail Pass a large vegetated median separates opposing traffic lanes, and structures under one set of lanes do not correspond to a structure under the opposing traffic lanes – five bridges occur under the eastbound lanes in this three-mile segment, and just one under the westbound lanes. Camera monitoring here was able to detect differences in species activity on the north and south sides of I-70. In 2010 (the only year in which monitoring was conducted on East Vail Pass), elk were regularly captured during the summer months by the cameras adjacent to the westbound lanes where there are no crossing structures – these sites documented the highest levels of elk activity within the study area (Figure 1). However, on the eastbound side of the interstate elk were captured at only one location (MP 192.0). These results indicate that elk may only minimally be using the large span bridges under the eastbound lanes, possibly because they cannot access them from the north side or perhaps because they can also cross at-grade and are not 'forced' to use the bridges (the one span bridge under the westbound lanes at Corral Creek was not monitored as a part of this study).

Other locations without an available structure (e.g., fill slopes across drainages) also recorded differences in species presence on the north and south sides of the interstate. Several locations captured high levels of activity on one side that were not matched on the other side. For example, at MP 251.8, one elk and 134 mule deer were detected on the north (westbound) side of I-70, whereas 31 elk and only 11 mule deer were detected on the south (eastbound) side (2009 data; only WB side monitored in 2010). A number of additional species, including black bear, bobcat, coyote, gray fox, red fox and raccoon were documented on the north side, but not on the south side. Other fill slope monitoring locations documented similar, if less dramatic, variations in species presence on the north and south of I-70.

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. These results suggest an inverse relationship between human activity and wildlife activity at existing and potential crossing locations, a correlation that has been documented in other studies (e.g., Clevenger and Waltho 2000).

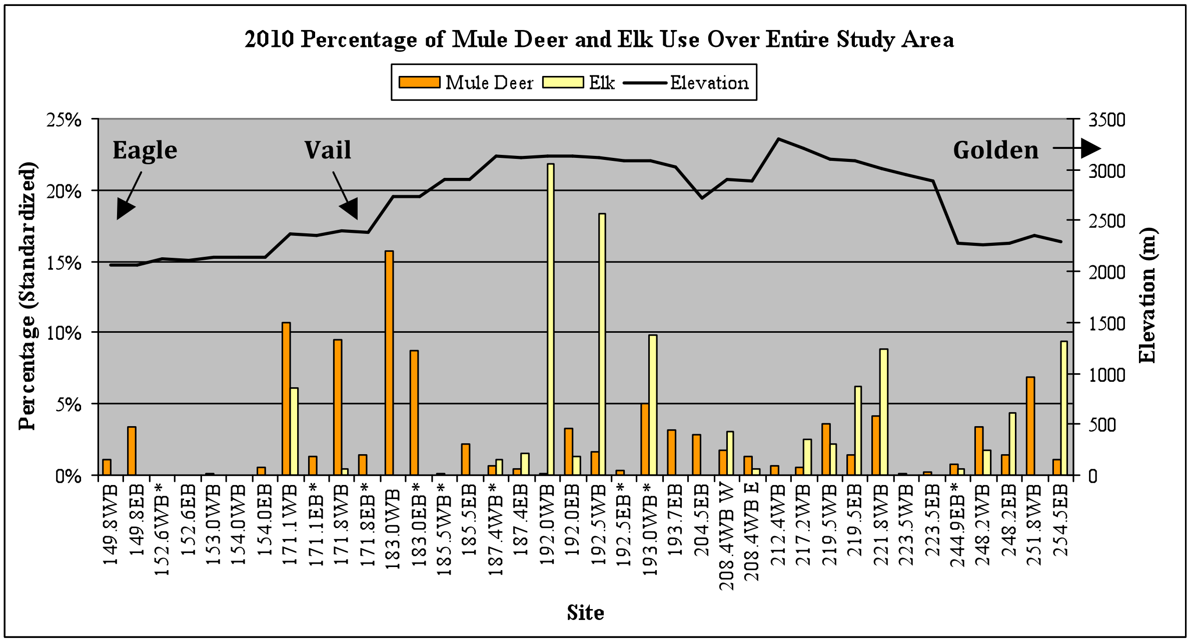


Figure 1: – Percentage of elk and mule deer use at monitoring locations in the I-70 Mountain Corridor in 2010.

** The camera at this site was functioning for less than 50% of the time for 1 or more months in the study period.*

Complete monitoring results are available in the "I-70 Eco-Logical Monitoring and I-70 Wildlife Watch Report" accompanying this report.

2.1.4. 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, seen along I-70 between Golden and Glenwood Springs (www.I-70WildlifeWatch.org). The website was developed by Western Transportation Institute at Montana State University specifically 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 roadkill counts or accident reports.

A number of complementary strategies were undertaken to teach the motoring public about I-70 Wildlife Watch and encourage people to participate. The website was publicly launched with a press event at CDOW headquarters in Denver, Colorado on November 9, 2009 in coordination with the Colorado Wildlife on the Move coalition which is composed of Rocky Mountain Wild, ECO-Resolutions, LLC, CDOT, 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. There are also links to the website on CDOT's traveler information webpage (www.cotrip.org/home.htm) and the I-70 CSS website (http://i70mtncorridorcss.com/corevalues/healthy-environment/wildlife).

Motorists are 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). First, users identify the location where they made the observation to the nearest tenth-mile using a map with a terrain background and highway exit information as cues. They are then required to answer several questions about their observation including: was/were the animal(s) roadkilled or alive, the location of the animal(s) in relation to the roadway, species, number of individuals sighted, date and hour of the sighting, highway exits the driver entered and exited on the trip when the sighting was made, and how many times the observer has driven the same section of highway prior to the observation date without making an observation. After submitting their observation, users have the option to input another observation or to see a compiled map of recorded observations.

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 (Figure 2).

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 are largely reliant upon collisions that were serious enough to report. A 2003 report from Canada

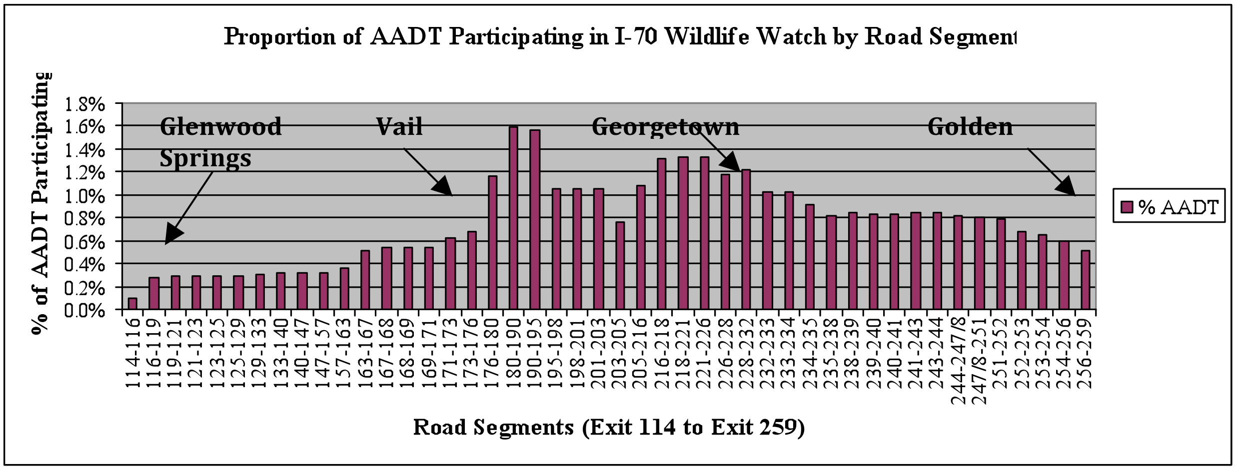


Figure 2: Proportion of Average Annual Daily Traffic (AADT) participating in I-70 Wildlife Watch for each roadway segment (Exit 114 to Exit 259).

states that collisions with wildlife resulting in an injury may be underreported by as much as 50%, and even higher underreporting rates are expected when wildlife accidents result only in property damage (L-P Tardiff & Associates Inc., 2003). Carcass observations from I-70 Wildlife Watch can be used to supplement traditional sources of AVC data and, over time, potentially capture roadkill hotspots or under-reported roadkills of small and medium bodied animals that may not be apparent 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. Figure 3 displays live and carcass observations of all species across the Corridor as compared to AVC counts derived from CSP accident reports, demonstrating different clusters in activity captured by each of these sources. Notably, the timeframe for the CSP data is markedly longer than that of the I-70 Wildlife Watch data, and changes in traffic volumes, roadway barriers and adjacent development over the 13 years of CSP data and the resulting impacts to AVC rates along the Corridor are not evident in this analysis. The effects of approximately 32 miles of continuous wildlife fencing in the western portion of the Corridor are not captured here, and as updated CSP datasets become available, the spike in reported AVCs seen from mileposts 147-167 is likely to diminish significantly as a result of the recently completed fencing. Future analyses of these data over common time periods will provide a more informative comparison.

The large spikes in I-70 Wildlife Watch observations at MP 228-232 relates to an area near Georgetown where bighorn sheep are known to linger near the roadway; however, other clusters of live observations would remain otherwise undocumented, such as the spike around MP 180-190 at West Vail Pass, which is primarily comprised of elk and mule deer observations. While mule deer, bighorn sheep and elk were most commonly recorded, observations of a number of other species were also made (Figs. 4 & 5).

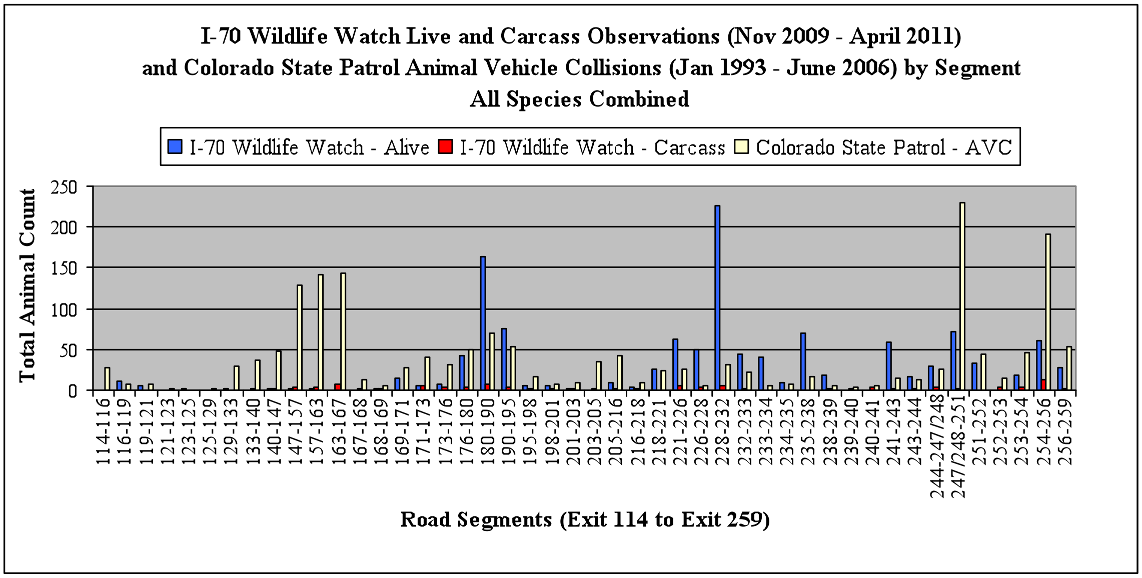


Figure 3: Comparison of I-70 Wildlife Watch observations (live animal and carcass) and AVC data from CSP per roadway segment. The CSP data covers 15 years, while the I-70 Wildlife Watch data captures only an 18 month period that does not overlap with the CSP data. Despite the different time frames, this graph demonstrates how these data sources capture different clusters of wildlife activity.

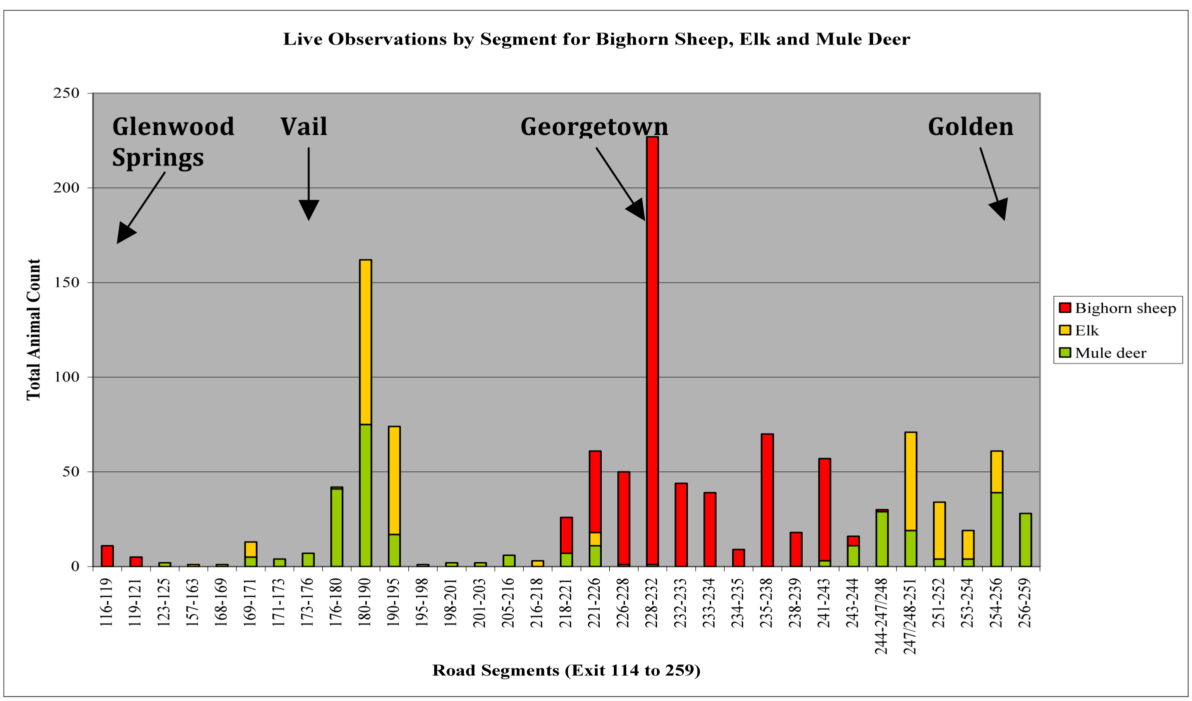


Figure 4: Total animal count by road segment for live observations of bighorn sheep, elk and mule deer. (Total n = 1196). Note roadway segments with no observations are not displayed in this graph.

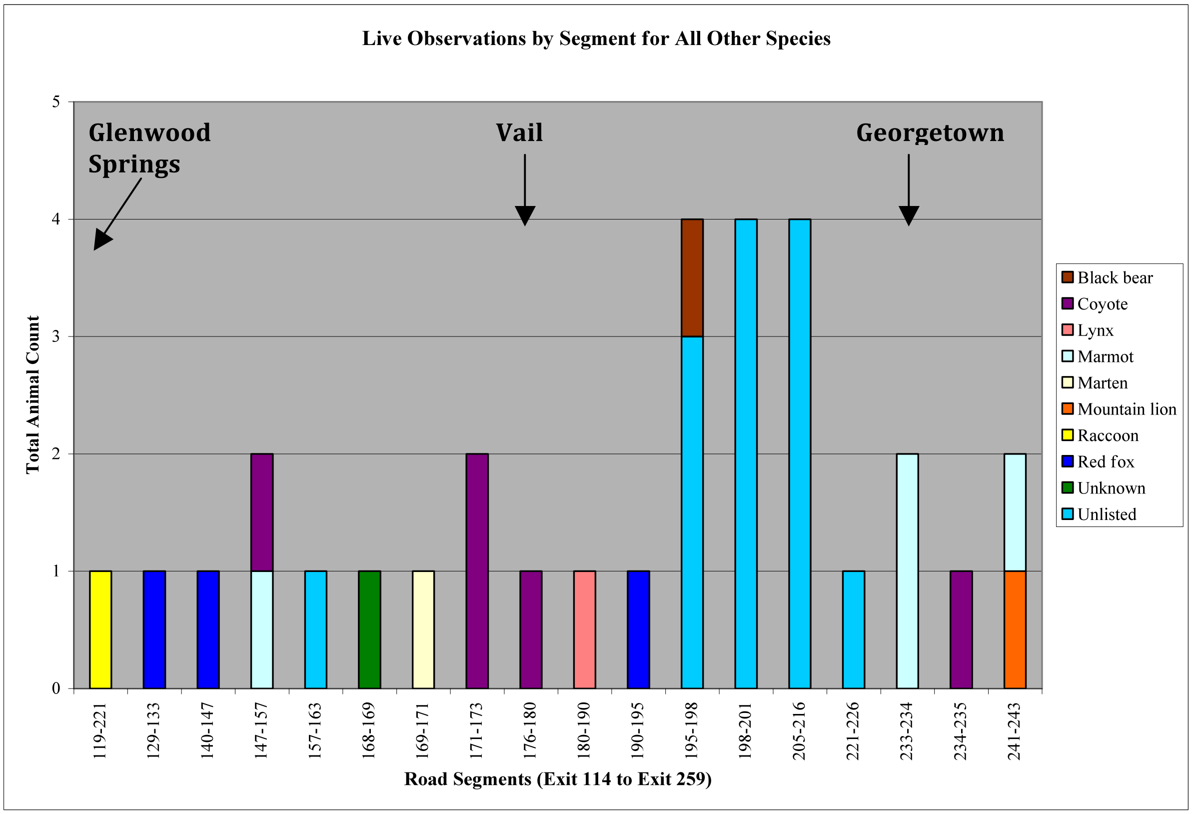


Figure 5: Total animal count by road segment for live observations on I-70 Wildlife Watch of black bear, coyote, lynx, marmot, marten, mountain lion, raccoon, red fox, and unknown and unlisted species. (Total n = 31). Note roadway segments with no observations are not displayed in this graph.

2.2. Defining Wildlife Movement Zones

The process of identifying specific terrestrial connectivity zones and priority road-stream crossing locations is an important step in ensuring the most efficient use of resources and directing mitigation dollars to locations with the greatest need for the greatest ecological benefit. Section 2.2.1 describes the analyses conducted to identify and delineate terrestrial wildlife movement zones (LIZs-2011); Section 2.2.2 describes how road-stream crossings were prioritized to highlight locations important for fish passage.

2.2.1. Linkage Interference Zones (LIZs-2011)

A major objective of the I-70 Eco-Logical Project was to apply updated datasets to refine and validate the 2004 LIZs, and to assess connectivity zones at the I-70 interface in the context of the larger ecosystem. This section of the report outlines the methods used to create a consistent and transparent process for identifying terrestrial connectivity zones in 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 originally described in 2004. A detailed methods report is available in *Appendix D*.

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 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 secondary criteria as appropriate.

To capture connectivity needs for the diverse array of wildlife present along this 130-mile roadway segment, the analysis required that at least one LIZ-2011 be identified within each of the study area's five bioregions (Table 2).

Table 2. Bioregions along the I-70 Mountain Corridor (CDOT 2004)

Bioregion	Mileposts
Western Slope Foothills	MP 130 – 170
Western Slope Montane	MP 170 – 182
Subalpine	MP 182 – 214 & MP 216 – 226
Alpine	MP 214 – 216
Eastern Slope Montane	MP 226 – 255

Suitable habitat is an important indicator of crossing activity (Barnum 2003). Primary parameters were derived from the compiled wildlife habitat as well as AVC data (Section 2.1.1). Some available data layers were excluded from the analysis because the data was too general or inconsistent across the study area. All parameters (i.e., target species or AVC data) and subparameters (i.e., habitat data layer, such as winter range) 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 fewer subparameters, 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. Canada lynx, Preble's meadow jumping mouse and boreal toad were each allowed a maximum possible score of 20, the highest possible. Lynx and Preble's are both listed as threatened under the Endangered Species Act, and boreal toad is a state endangered species and was on the candidate species list until the mid-2000s. River otter was given a maximum possible score of 12 because of its state threatened status.

For each focal species parameter, subparameters were identified, representing the different habitat values for that 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 (2008) rankings for priority wildlife habitat for economic species and species at risk were used as a guideline for prioritizing and scoring subparameters. 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. occupied habitat) were given a higher individual score than more general habitat types (e.g. overall range), unless the CDOW (2008) rankings used for guidance dictated otherwise. Modeled wildlife linkages (SREP 2008) were given the highest individual subparameter score because they indicate areas of the landscape that have been specifically identified as important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences and dispersal abilities).

The modeled wildlife linkages (SREP 2008) were also given the highest subparameter score for common species such as bighorn sheep and mule deer because these data layers relate directly to movement areas for these species. Sensitive habitat types, such as winter range, were given an individual subparameter score based on the CDOW rankings. Certain data layers, such as highway crossings, were included even though they were not ranked by CDOW because they were deemed important in the context of this study. These data layers were given a score based on scores for comparable data layers. See the full methods report in *Appendix D* for a list of all parameters, subparameters and their maximum allowable values.

The most up-to-date AVC data available from Colorado State Patrol were used for all species except mountain lion, black bear and lynx. For these three species, a separate dataset maintained by CDOW was used as this dataset includes all collected roadkill incidents for these species, not just those with a written accident report. Animal-vehicle collision data collected from both agencies were related to the nearest 1/10th mile and summed to obtain the total number of AVCs per 1/10th mile.

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. Each 1/10th mile segment then received a total score based on the sum of all the parameters occurring in that segment, and smoothed with the two adjacent segments to acknowledge that one segment is likely influenced by its neighboring segments (Huijser et al. 2008). Based on the smoothed scores, the 20th, 40th, 60th, 80th, and 100th percentiles were calculated.

Once the prioritization of 1/10th mile segments was completed, the next step was to apply a set of decision rules to provide a consistent process for delineating individual LIZs-2011 within the Corridor. The following suite of decision rules were applied to define LIZs-2011:

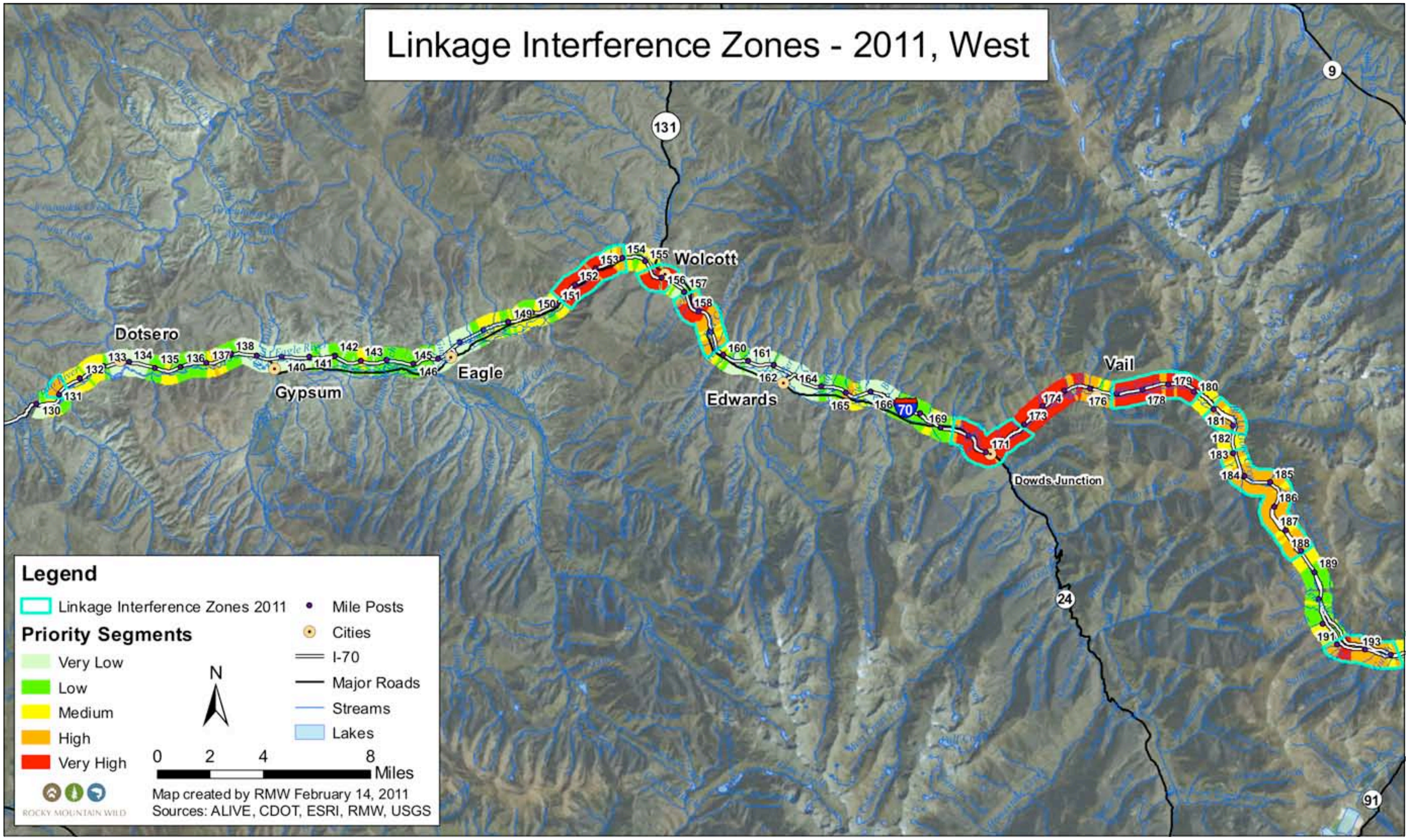
- The minimum length for a LIZ is ½ mile (i.e., five 1/10th mile segments);
- Any Very High or High 1/10th mile road segment (i.e., 60-100th percentile) is automatically included in a LIZ;

- Up to ½ mile of continuous Medium-ranked road segments (40-60th percentile) are included in a LIZ if surrounded by Very High or High-ranked road segments;
- A single 1/10th mile Low priority road segment (below the 40th percentile) is included in a LIZ only if it is surrounded by Very High or High road segments or within an included Medium-ranked segment;
- A Low priority road segment 2/10th mile long or greater marks the end of a LIZ;
- A LIZ may cross bioregions.

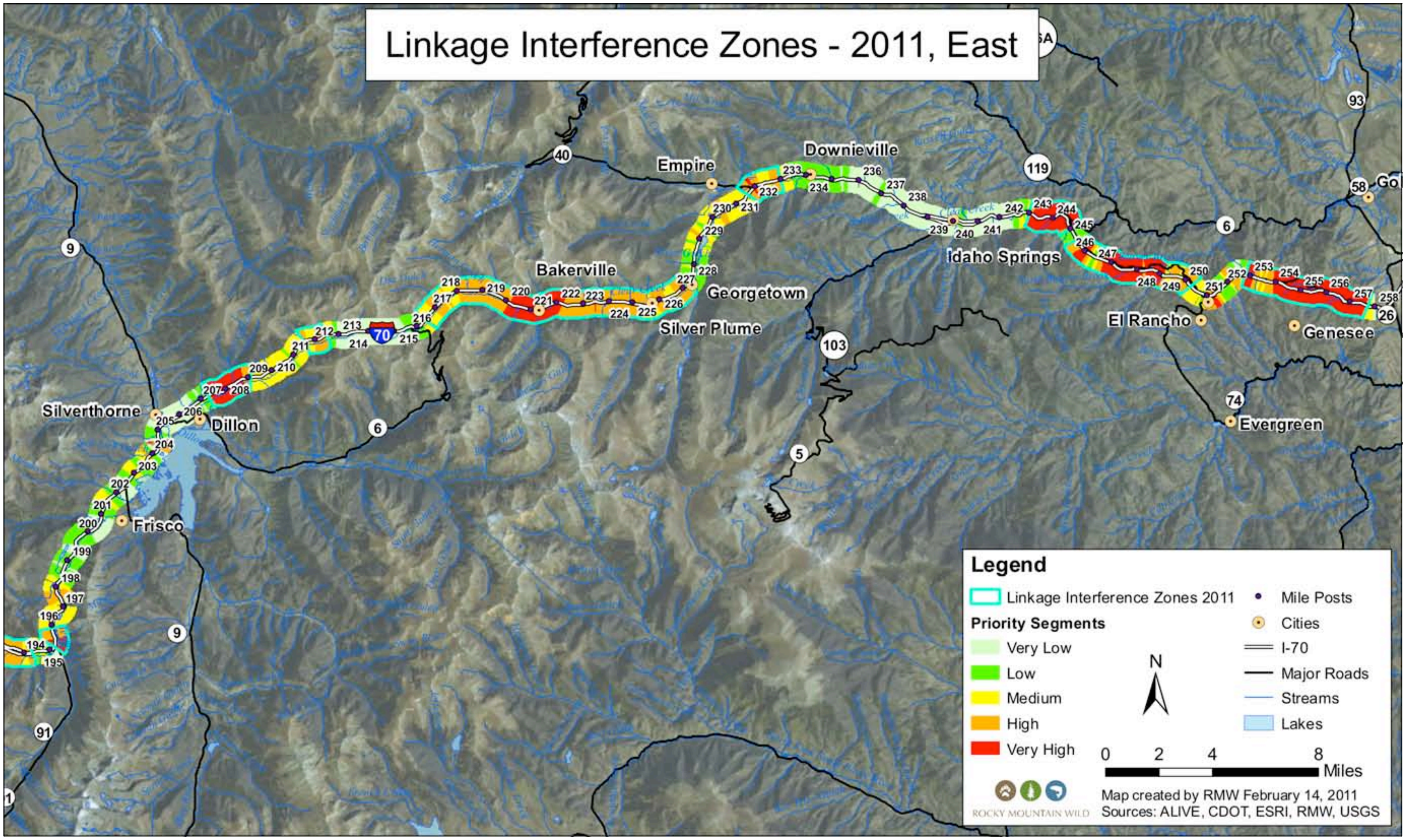
LIZs-2011 were then further refined to exclude heavily developed areas along the highway corridor. Aerial imagery was used to conduct this refinement instead of the GIS land use/land cover layer, which coarsely generalizes land use. In this manner, major developed areas along the Corridor, such as the Town of Vail, were excluded, while still including other residential areas where wildlife may still pass (e.g., low-medium density residential areas). This analysis process and the resulting connectivity zones underwent a thorough review process by the ALIVE committee, leading to several revisions and iterations before the final LIZs-2011 were confirmed.

Using this analysis procedure, 17 distinct connectivity zones representing four of the five bioregions were identified along the I-70 Mountain Corridor (Maps 4 – 7). The alpine bioregion, the only one not represented in the LIZs-2011, is only two miles long and there is a land bridge over the interstate for most of its length where I-70 travels through the Eisenhower/Johnson Tunnels under the Continental Divide. Across the Corridor, the primary parameters with the greatest influence on how the LIZs-2011 were defined are: elk, mule deer, lynx, and AVC counts. Within a LIZ-2011, any species parameter that scored half or more of the maximum score possible for that parameter across at least half of the area encompassed by that LIZ was identified as a primary target species for that LIZ. Other species occurring within the LIZ, but with less influence on defining the LIZ are considered secondary target species. For a full description of the primary parameters that drove the identification of individual LIZs-2011, see the full analysis methods report in *Appendix D*. Primary and secondary target species for each LIZ were reviewed by CDOW biologists and adjusted as appropriate to accommodate connectivity needs for the diversity of wildlife, including those which may not be sufficiently captured by the LIZ-2011 analysis due to a paucity of data. For example, mule deer was upgraded to a primary target species at LIZ E, Dowds Junction, because this is a critical point in the deer migration corridor; mountain lion, a habitat generalist important predator species for which there is little spatially explicit data, was added as a secondary target species to several LIZs-2011 with important prey species habitat.

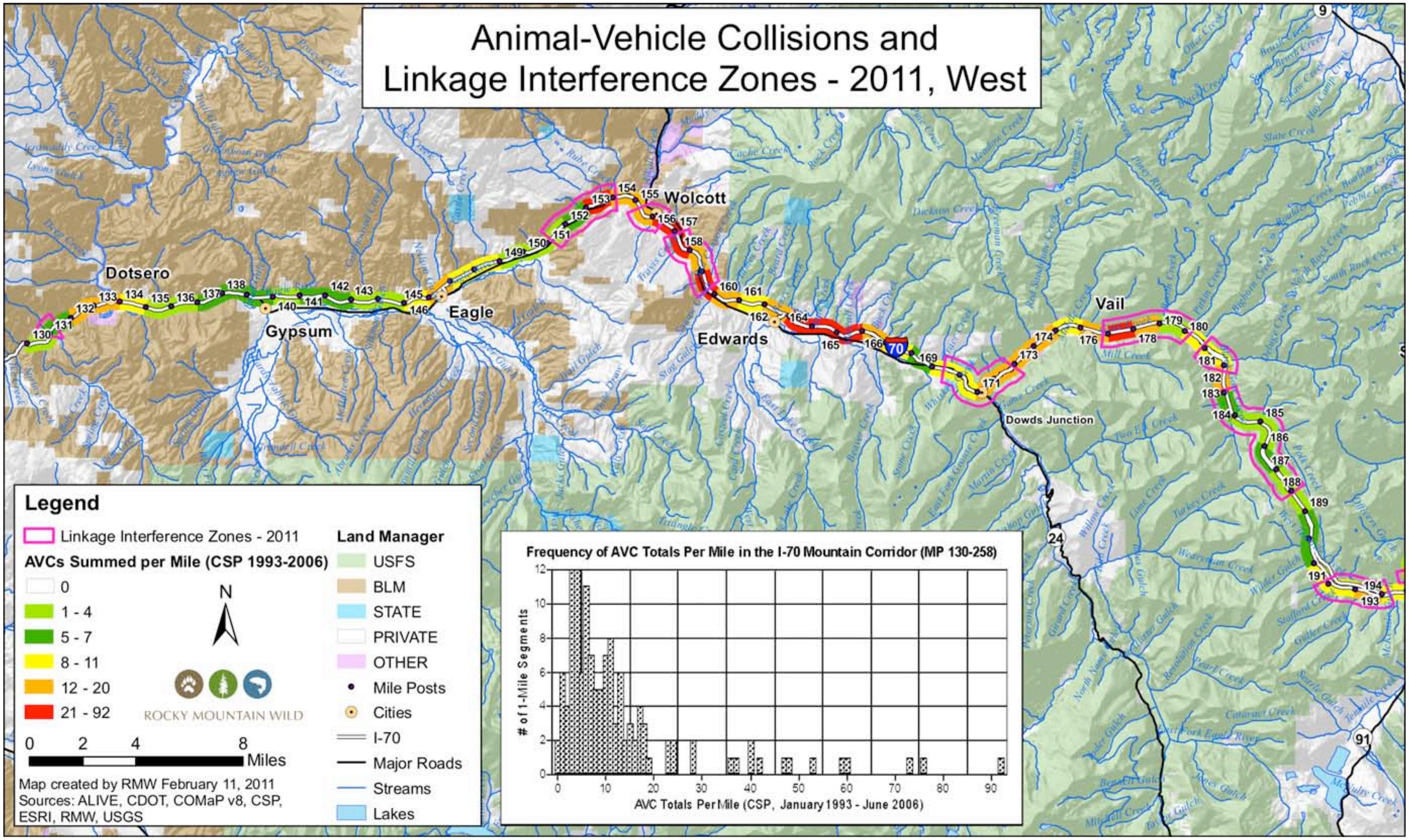
A comparison of the 2011 and 2004 LIZs demonstrates locations identified in both analyses as well as several that were only identified in one or the other. Compared to the LIZs-2004, the LIZ-2011 analysis identified more discrete connectivity zones.



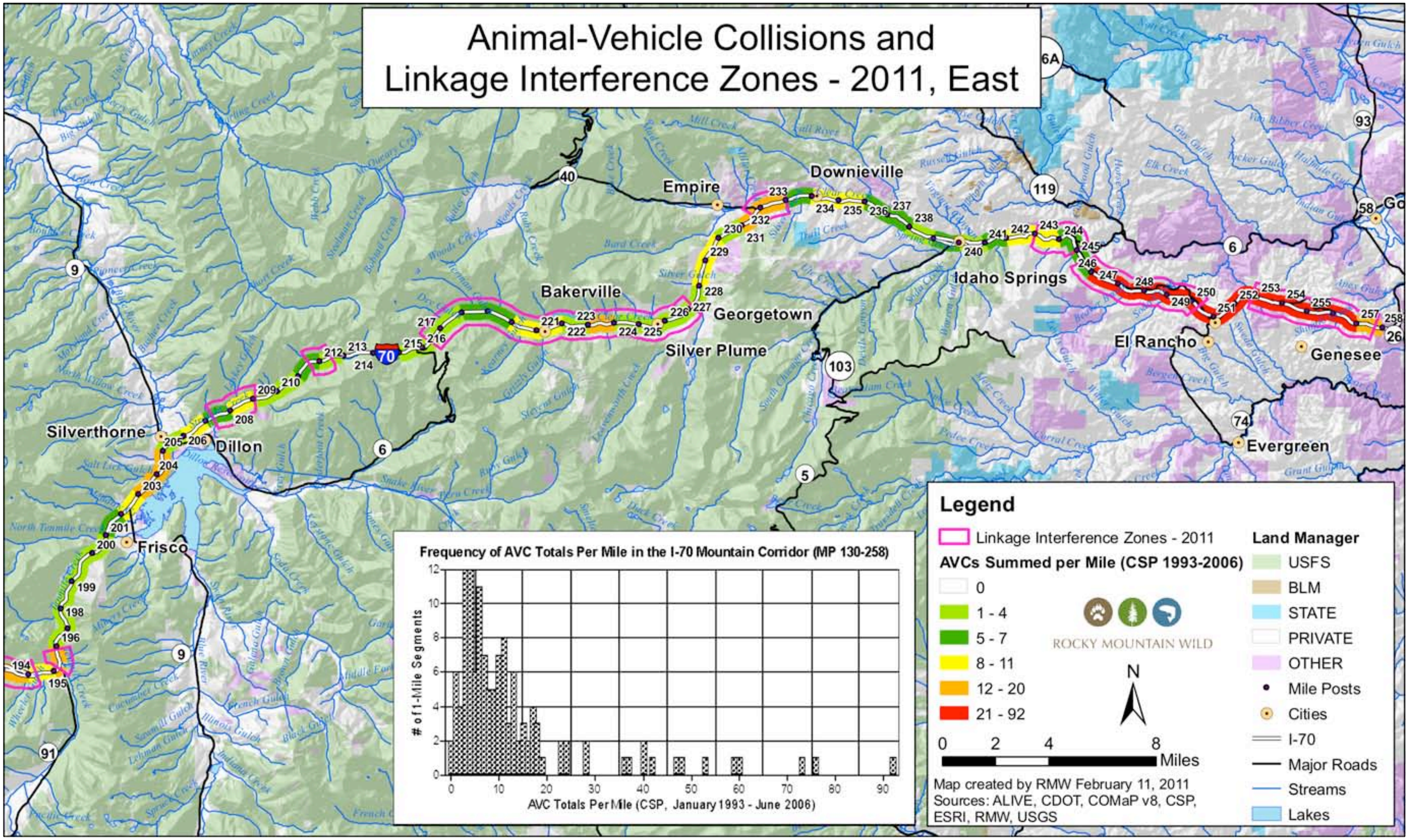
Map 4. LIZs-2011 in the western portion of the study area from Dotsero to East Vail Pass. Turquoise outlined areas define the LIZs-2011; background colors represent the ranking of 1/10th mile roadway segments.



Map 5. LIZs-2011 in the eastern portion of the study area from Copper Mountain/Wheeler Junction to Golden. Turquoise outlined areas define the LIZs-2011; background colors represent the ranking of 1/10th mile roadway segments.



Map 6. LIZs-2011 (pink outlined areas) in the western portion of the study area, from Dotsero to East Vail Pass with summed animal-vehicle collision counts in the background.

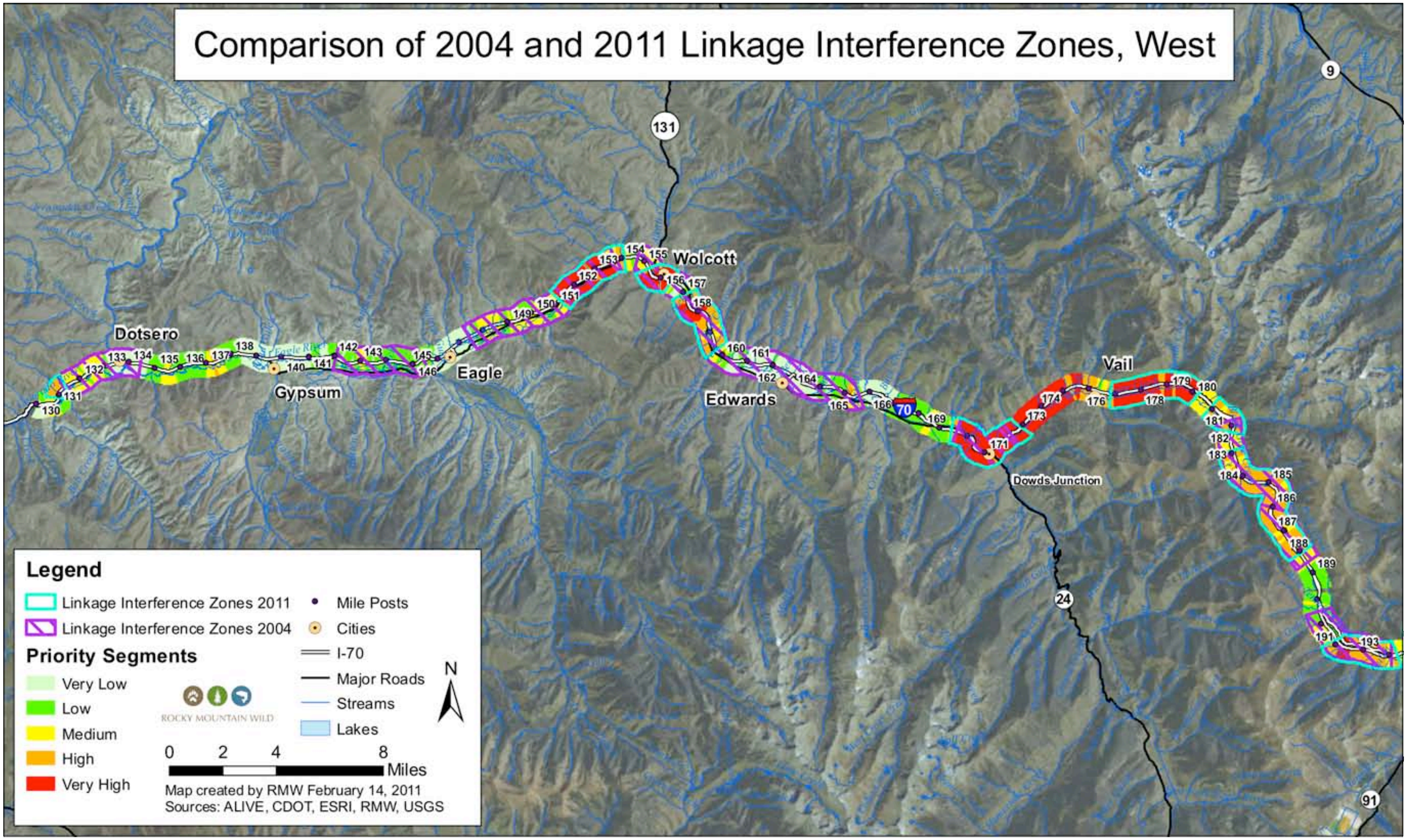


Map 7. LIZs-2011 (pink outlined areas) in the eastern portion of the study area from Copper Mountain/Wheeler Junction to Golden with summed animal-vehicle collision counts in the background.

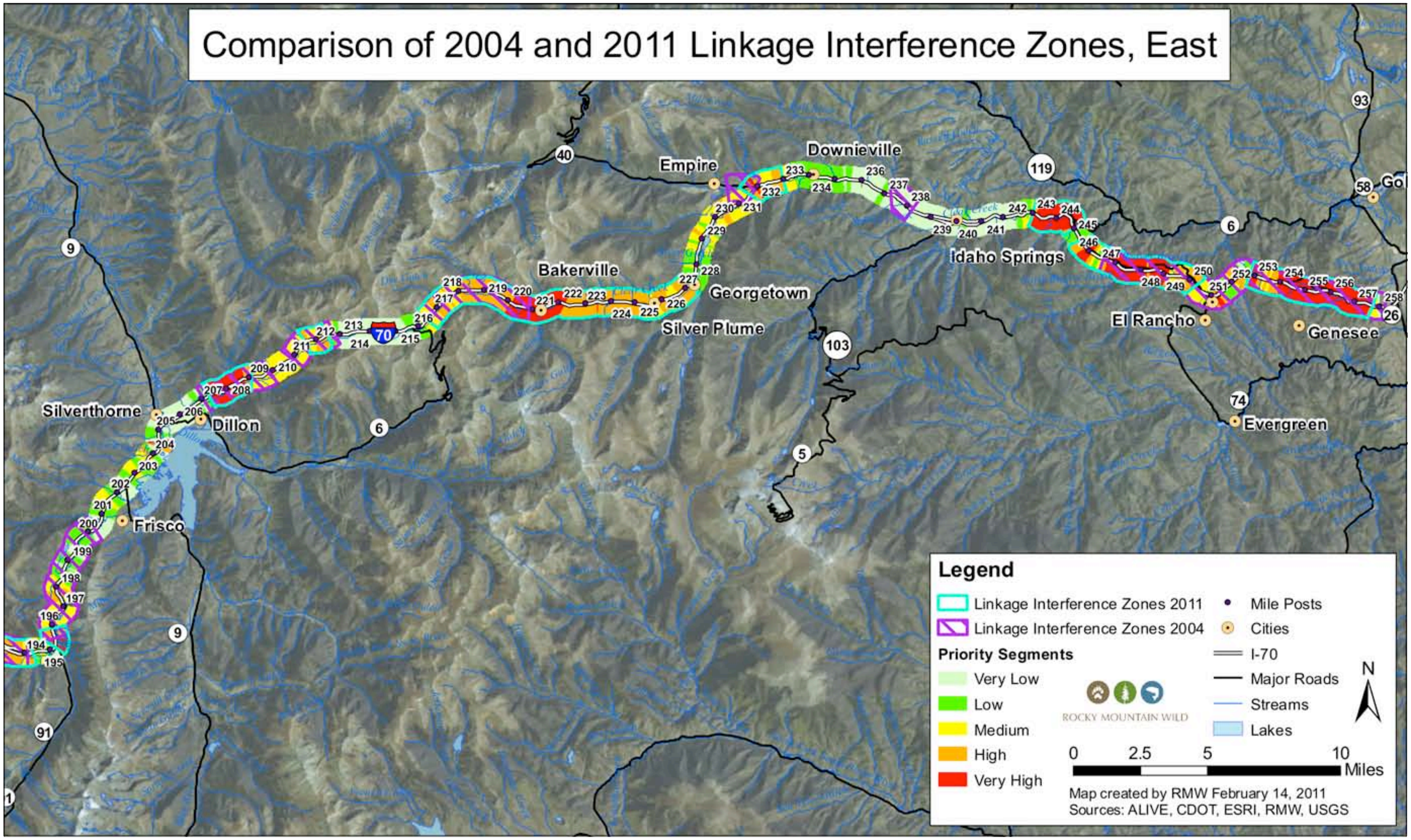
Seventeen LIZs, covering approximately 51 miles, were identified in the 2011 analysis, compared to 13 zones encompassing 65 miles in 2004. The 2004 analysis also includes two LIZs for which sub-segments were identified, specifically, LIZ 6 a & b, (Upper and Lower West Vail Pass) and LIZ 9 a & b (Laskey and Hamilton Gulch to Dead Coon Gulch). While both analyses incorporated many of the same types of data layers, the LIZ-2004 process was based on expert assessment of the available data layers. In addition, the specifics of the LIZ-2004 analysis process are not well documented, and so the process is not repeatable with more up-to-date datasets. Table 3 provides a side-by-side comparison of the LIZs identified in each analysis (Maps 8 & 9).

Table 3. Comparison of 2011 and 2004 LIZs. For each LIZ-2011, the approximately corresponding LIZ-2004 is listed. In some cases, there is a LIZ identified in one analysis that was not identified in the other. In other cases, two LIZs-2011 may correspond to a single LIZ-2004, as, in general, longer segments were identified in the 2004 analysis while the 2011 analysis defines more concise zones.

LIZ-2011	Mileposts	LIZ-2004	Mileposts
Zone A (Dotsero)	130.9-131.3	LIZ 1 (Dotsero)	131.4-134.5
N/A		LIZ 2 (Eagle Airport to Town of Eagle)	142.0-145.3
Zone B (Wolcott West)	151.2-154.1	LIZ 3 (Eagle to Wolcott)	147.3-153.6
Zone C (Wolcott)	155.3-156.3	LIZ 4 (Wolcott to Avon)	154.4-166.5
Zone D (Wolcott East)	157.1- 159.6	LIZ 4 (Wolcott to Avon)	154.4-166.5
Zone E (Dowds Junction)	169.4-172.8	LIZ 5 (Dowd Canyon)	169.5-172.3
Zone F (Vail - East)	176.8-180.1	N/A	
Zone G (Gore Creek)	180.9-182.1	N/A	
Zone H (West Vail Pass)	182.9-188.1	LIZ 6a&b (West Vail Pass)	181.7-188.5
Zone I (East Vail Pass)	191.8-194.2	LIZ 7 (East Vail Pass to Copper)	190.4-194.0
Zone J (Wheeler Junction)	195.2-195.8	LIZ 8 (Officer's Gulch/Owl Canyon)	195.5-200.9
Zone K (Laskey Gulch)	207.3- 209	LIZ 9a (Laskey Gulch)	207.0-209.7
Zone L (Hamilton Gulch)	211.6-212.4	LIZ 9b (Hamilton Gulch to Dead Coon Gulch)	210.7-212.6
Zone M (Bakerville)	216.4-227.1	LIZ 10 (Herman Gulch to Bakerville)	216.7-220.8
Zone N (Empire Junction)	231.6-232.9	LIZ 11 (East of Empire on US 40)	I-70 Exit 232
N/A		LIZ 12 (Fall River)	237.2-238.2
Zone O (Clear Creek Junction)	243.0-244.9	N/A	
Zone P (Beaver Brook)	245.5-250.2	LIZ 13 (Mt Vernon Canyon)	246.5-258.1
Zone Q (Mt Vernon Creek)	252.8-257.6	LIZ 13 (Mt Vernon Canyon)	246.5-258.1



Map 8. LIZs-2011 (turquoise outlined areas) as compared to the LIZs-2004 (purple hashed areas) in the western portion of the study area from Dotsero to East Vail Pass. Background colors represent the ranking of 1/10th mile roadway segments.



Map 9. LIZs-2011 (turquoise outlined areas) as compared to the LIZs-2004 (purple hashed areas) in the eastern portion of the study area from Copper Mountain/Wheeler Junction to Golden. Background colors represent the ranking of 1/10th mile roadway segments.

2.2.1. Aquatic Connectivity Locations

Many of the culverts currently in place in the nation's road network were designed with the singular purpose of drainage efficiency, without regard for stream channel continuity or fish passage (Normann et al 2005). The objective for this component of the I-70 Eco-Logical Project was to conduct a preliminary assessment to determine, first, where connectivity for fish passage is needed; second, whether a road-stream crossing presents a barrier to fish passage at these locations, and if so, identify the features that render the crossing a barrier; and, finally, determine whether the crossing can be retrofit to improve fish passage or if new crossing structure is needed at that location. This type of initial inventory is important for prioritizing stream crossings that block access to aquatic habitats, implementing appropriate retrofits, where feasible, and designing new replacement crossings that encompass the full range of aquatic and terrestrial connectivity needs at a given location (California Department of Transportation 2007, USFS 2008). For the purposes of the I-70 Eco-Logical Project, aquatic connectivity focuses on fish passage and does not consider connectivity needs for other types of aquatic organisms.

Two criteria were used to determine whether a road-stream crossing is a priority for aquatic connectivity; namely, the presence of a target species, and an absence of intentional barriers along the stream segment. Data obtained from CDOW stream monitoring stations were used to derive a list of target species at each road-stream crossing[2]. In some cases, a stream sampling location was not directly on the stream in question; for example, where the road-stream crossing is on a tributary and the sampling site is on the mainstem. In these instances the nearest sampling site in the stream network was used to represent species presence for the stream segment. Where there was no sampling site within miles upstream or downstream of the road-stream crossing the target species is listed as 'unknown'.

Intentional barriers in a stream network protect pure, native fish from hybridizing with stocked or introduced strains, and protect against the spread of invasive species or diseases to these pure populations (USFS 2008). Information on intentional manmade and natural barriers to aquatic passage on streams within the Corridor was obtained from the individual district biologists that oversee each of the watersheds in the project area, as this information is not available through a centralized database. Barriers are sometimes located upstream from the I-70 road-stream crossing, in which case connectivity at the road-stream crossing may or may not be a priority. Streams with barriers are located on the mainstem rather than at the inventoried tributary require further consultation with CDOW aquatic biologists to determine whether fish passage is a priority at that crossing location. Stream

[2] CDOW is by statute (C.R.S. 33-1-101; 33-1-105; 33-1-110(4)) the authoritative source for all aquatic data in the state and the data provided by CDOW is the best available fish data in Colorado. Sampling protocols at each site varies depending on the purpose of the current sampling project. Sometimes only data on specific species are collected while other times the whole assemblage is targeted (H. Vermillion, CDOW, pers. comm., March 2011).

segments under consideration for the restoration of cutthroat trout may have a new barrier introduced in the future to preserve the conservation population in that segment.

Any site with target species present or unknown, and without an intentional barrier was considered a priority location for fish passage, although sites with target species unknown will need additional consultation with CDOW and/or surveys to confirm species presence. For each of these locations, the degree to which an I-70 road-stream crossing acts as a barrier or facilitates fish passage was determined through the roadway inventory (Section 2.1.2.). Aquatic inventory questions were designed to identify specific features, such as natural substrate continuity, outlet drops, pooling, channelization, baffles and so on, allowing the researchers to assess functionality for fish passage. While comprehensive modeling tools (e.g., USFS FishXings Software) are available to guide stream simulation designs, the purpose of this assessment was simply to initially evaluate aquatic connectivity conditions at prioritized locations. Information from the roadway inventory further helped guide the development of preliminary recommendations for enhancing or restoring fish passage at each priority road-stream crossing.

2.3. Connectivity Recommendations

Connectivity recommendations were developed with the goal of providing the best mitigation in the best places, as advised by the Eco-Logical framework (Brown 2006), and maintaining a consistent vision for connectivity across the Corridor. Recommendations for improving permeability for terrestrial wildlife are focused in the LIZs-2011, although additional measures may be warranted at other locations throughout the Corridor. Best management practices provide guidance for designing and enhancing crossing structures regardless of whether a location is within or outside of a LIZ (Section 2.3.1).

Specific sites for locating recommended wildlife crossing structures were determined by a number of factors. Primary considerations included:

- Presence of an existing culvert or bridge that may be retrofit, if possible, or replaced, if necessary;
- Local topography that may facilitate (e.g., ridgelines or drainages) or impede wildlife movement (e.g., sheer cliffs);
- Recommended spacing between safe passage opportunities based on target species;
- Existing or potential land protection and land use adjacent to the roadway and within the larger landscape corridor.

Recommended spacing between crossing structures within a LIZ depends on connectivity goals (e.g., genetic connectivity, seasonal or daily movements for individual or multiple species), movement behavior and capacity of the target species (e.g., wide ranging vs. low mobility). Connectivity goals for the I-70

Mountain Corridor include providing routes for seasonal migrations, allowing wildlife whose home ranges are bisected to access habitat on both sides of the road, and providing opportunities for dispersing individuals. Huijser et al (2008) offers a method for calculating the optimal spacing between crossing opportunities based on the diameter of a species home range sizes. Ultimately, however, spacing requirements depend upon whether cross-roadway movements are migratory, dispersal or daily in nature, and how the road bisects the animal's home range (through the middle vs. near the edge). Approximate home range sizes for each of the target species within the I-70 Mountain Corridor are provided in *Appendix A*, where such information was available.

Analyses of individual home ranges along the I-70 Mountain Corridor were not conducted for this project. Instead, more general rules of thumb were applied based on research studies of various species types. In general, wildlife crossings spaced at one mile or shorter intervals will capture most of the movement needs for large animals in North America (Bissonette and Adair 2008), assuming the presence of suitable habitat. Clevenger et al (2001*a*) note that medium-sized animals need structures every 500-1000 feet. Smaller animals, such as voles, mice and squirrels, that move shorter distances require even more frequent crossings, spaced every 150-300 feet (Bates 2003), although Smith (2003) notes that a maximum distance of 1,066 feet (0.2 miles) between crossings corresponds to 75% use by small mammals. Meanwhile, 150-300 feet is the recommended spacing between crossings for amphibians and reptiles, depending on the target species (Puky 2003). All of these spacing guidelines must be placed in the appropriate landscape context, as landscapes that are already highly fragmented offer few crossing opportunities (i.e., bottlenecks), whereas in an unfragmented 'low contrast' landscape more wildlife crossing opportunities are needed (Clevenger and Huijser 2011). For the purposes of determining spacing between wildlife crossing opportunities on I-70, these recommended distances were combined with the actual landscape characteristics to determine specific crossing locations along the Corridor.

In addition to placing structures in the right location, crossing structure design requires careful attention to ensure that structures are functional for the target species. In determining the best crossing structure type for a given location, DOTs must consider topographic suitability (e.g., underpass vs. overpass) and engineering constraints and cost efficiencies, as well as target species preferences. Some species (e.g., small prey animals) require structures with adequate cover, while others (e.g., elk) require very open structures with clear lines of sight (Cramer et al 2011*b*), and still others (e.g., bighorn sheep) may require overpass structures to move both males and females in a population (McKinney and Smith 2006). To accommodate multiple species types, a diversity of crossing structure types (overpasses, bridges, arch culverts, etc) should be available within a connectivity zone (Clevenger and Waltho 2005; Clevenger and Huijser 2011).

The final *I-70 Connectivity Recommendations* (*Appendix E*) were developed by applying these guidelines from current research to specific sites within the LIZs-

2011. Compiled data from the roadway inventory was integral to the recommendations development process, and was complemented with the habitat and AVC data layers to determine site-specific needs. Data from the camera monitoring and the I-70 Wildlife Watch website were used to further refine the recommendations by providing pertinent information about wildlife presence and activity at specific locations along the Corridor. For each LIZ-2011, the Species Movement Guilds of each target species within that LIZ are listed, as these guilds can be used in Tier 2 planning to refine mitigation strategies to carefully consider the behavior and preferences of each target species (Kintsch and Cramer 2011).

Wherever feasible, recommendations for improving the existing roadway infrastructure to promote wildlife passage are provided, and include improvements such as retrofitting existing bridges and culverts, or conducting maintenance activities, such as clearing vegetation or removing sediment, to render structures more functional for wildlife passage. These are low-cost activities that may be conducted outside of projects. A full list of these 'Early Enhancement Opportunities' is available in Section 4.1. Where no such enhancement opportunities are available, recommendations for new wildlife crossing structures are provided. The complete *I-70 Connectivity Recommendations*, available as both a utilitarian spreadsheet and as a readable word document (*Appendix E*), are referenced in the LIZs-2011 and wildlife inventory locations data layer on the CSS map server, and are easily linked to by users of the CSS website.

Wildlife fencing is an effective complement to crossing structures, directing animals unfamiliar with a structure towards the passageway (Clevenger and Waltho 2000, Clevenger et al 2001*b*, Dodd 2007*c*). While wildlife fencing alone can effectively reduce AVC rates (Huijser et al 2009), it is not recommended as a stand-alone mitigation measure. Continuous wildlife fencing increases the overall barrier effect of a roadway, leading to population isolation if fencing is not installed in conjunction with suitable wildlife crossing structures (Huijser et al 2008, Huijser et al 2009). For the I-70 Mountain Corridor, short stretches of wildlife fencing (< 1 mile) designed to guide wildlife to crossing structures is recommended over continuous fencing, at substantially lower cost, except in areas where multiple structures in close proximity can be connected via fencing. Where limited crossing opportunities are available in the 32-mile fenced segment in the western portion of the study area, new crossings should be prioritized to reduce the overall barrier and provide safe crossings.

In implementing the connectivity recommendations it is important for Tier 2 project teams to consider the primary and secondary target species for each LIZ and how they influenced the LIZ identification process, as it is possible that one target species drove rankings in one portion of the LIZ while a different species drove the ranking in another portion of the LIZ. While the entire LIZ-2011 is important for wildlife connectivity, it is possible that not all target species need to be equally considered at all mitigation sites throughout the LIZ. Additional species that may not have been adequately captured through the LIZ-2011 analysis process will also warrant further consideration. Field surveys during Tier 2 planning processes should seek to refine species considerations at specific sites to capture the movement needs of all species at that site, as appropriate.

Future development along the Corridor was not considered in the development of connectivity recommendations. Ongoing collaborative processes are therefore essential for coordinated planning with local communities along the I-70 Mountain Corridor. Compatible land use and zoning in areas adjacent to the interstate and within landscape movement areas requires, first, that county and municipal planners are informed of wildlife mitigation plans at the highway interface. Public land ownership, private preserves or conservation easements are all compatible with wildlife crossing structures, however, the management of these lands must also be compatible with wildlife activity. Grazing, mineral extraction, motorized recreation, developed recreation, and other high-density recreation activities should be avoided in the approaches to wildlife crossing structures to minimize human incursions and impacts to wildlife habitat and facilitate wildlife use of these structures. 'Quiet' recreation uses, such as hiking, mountain biking, snowshoeing, and backcountry skiing/riding should also be limited in the immediate approach to a dedicated wildlife crossing.

In some cases, communities and DOTs may consider installing wildlife crossings in areas without designated protections as continuously protected lands are limited in many portions of the Corridor. For example, the Mt Vernon Creek LIZ (Q) and Beaver Brook LIZ (P) traverse almost entirely private lands, except for one area owned and managed by Denver Parks. Through much of these areas, homes are widely spaced and elk and deer herds as well as carnivores move regularly through the hills. Compatible zoning to prevent higher density development may be sufficient to accommodate wildlife needs in this area, and new wildlife crossing structures would go a long way towards reducing the high AVC rates characteristic of these LIZs.

Recommendations for restoring or improving conditions for fish passage at road-stream crossings were similarly developed for any stream with target species confirmed present or unknown. In general, it is recommended that passage be provided at any stream with a history of or potential for supporting native fish (USFS 2008), unless there is a distinct reason for preventing passage at certain locations, for example to protect native cutthroat trout populations or to prevent the spread of whirling disease, which is found in a number of streams on the Western Slope. The objective of the aquatic connectivity recommendations are to mimic the natural stream processes and upstream and downstream conditions inside the structure to the greatest extent possible (Massachusetts Department of Transportation 2010). Controlling water velocity and minimizing outlet drop are major factors influencing successful through-passage (Cahoon et al 2007), and were identified as constraints at a number of road-stream crossings in the Corridor. Providing sufficient flow depth and adding natural substrate to culverts were also commonly identified needs. Wherever appropriate, the recommendations are designed to integrate terrestrial and aquatic connectivity needs at a site.

Tier 2 consideration of these aquatic connectivity recommendations will require additional consultation with CDOW biologists to ensure that project-level designs account for special considerations for specific species or life stages that affect through-passage abilities such as maximum tolerable water velocity and jumping height (Kilgore et al 2010). Future planning should further consider each road-stream crossing in the context of the entire watershed and the location of other barriers in the stream network. A Montana study of a stream network found a very low probability that an individual fish could successfully pass through all the culverts in the network, even when each culvert independently was shown to be passable, indicating the importance of cumulative impacts (Cahoon et al 2007).

2.3.1. Connectivity Guidelines

In addition to site-specific or LIZ-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. The guidance includes practices for siting and designing pipes, culverts and bridges to facilitate wildlife passage, and include guidelines for retrofitting existing structures as well as construction guidelines to minimize impacts to wildlife and habitat connectivity.

These guidelines, entitled *I-70 Guidelines for Enhancing Wildlife Permeability* (*Appendix F*), were first conceived by CDOT biologists around 2005. They were then revised, updated and expanded in 2010-2011 as a part of the I-70 Eco-Logical Project, including the addition of guidelines for fish passage. This revision 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 guidelines are not limited to application within the LIZs-2011; indeed they may be referenced for any transportation project, particularly those where a bridge or culvert is being installed or replaced to incorporate wildlife-friendly characteristics into all new structures. Nor are the guidelines specific to I-70; they are not location specific and may be applied to projects throughout Colorado.

The purpose of I-70 Eco-Logical Project is to inform Corridor-wide planning and feed into projects as Tier 2 planning processes commence. Accordingly, the *I-70 Connectivity Recommendations* and *Guidelines for Enhancing Wildlife Permeability* offer practical guidance to feed into project-level planning and design. For more details on siting and designing effective wildlife crossing structures and other mitigation measures the researchers recommend a number of resources (see Box), with a caution to readers that some mitigation solutions may not be viable techniques for implementation on a high volume interstate such as I-70.

Select Resources for
Designing Wildlife Crossing Structures

Guidelines for Terrestrial Wildlife

- Clevenger, A. P. and M. P. Huijser. 2011. Wildlife crossing structure handbook: design and evaluation in North America. Report to the Federal Highway Administration. Publication No. FHWA-CFL/TD-11-003. Western Transportation Institute, Bozeman, Montana.
    - http://www.cflhd.gov/programs/techDevelopment/wildlife/
    - This report to FHWA includes detailed Hot Sheets describing species-specific guidelines for each of the different structure types.

- Arizona Game and Fish Department. 2008. Guidelines for Bridge Construction or Maintenance to Accommodate Fish and Wildlife Movement and Passage. Arizona Game and Fish Department, Habitat Branch, Phoenix, AZ.
    - www.azgfd.gov/hgis/pdfs/BridgeGuidelines.pdf

- Wildlife and Roads Website
    - Offers decision making guidance and resources on evaluating the use and effectiveness of wildlife crossing structures.
    - http://wildlifeandroads.org

- Massachusetts Department of Transportation. 2010. Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams. Massachusetts Department of Transportation. Boston, MA.
    - http://www.mhd.state.ma.us/downloads/projDev/Design_Bridges_Culverts_Wildlife_Passage_122710.pdf

- Kintsch, J. and P. C. Cramer. 2011. Permeability of existing structures for terrestrial wildlife: a passage assessment system. Research Report No. WA-RD 777.1. Washington Department of Transportation. Olympia, WA.
    - The Passage Enhancement Toolbox compiled for this report provides photo examples of enhancements that can be made to existing structures to render them more functional for wildlife passage.
    - http://www.wsdot.wa.gov/Research/Reports/700/777.1.htm

Guidelines for Fish Passage

- USDA Forest Service stream crossing guidelines
    - http://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/index.shtml

- Massachusetts Department of Fish and Game stream crossing handbook
    - http://www.mass.gov/dfwele/der/freshwater/rivercontinuity/guidancedoc.htm

CHAPTER 3

Foundations of a Regional Ecosystem Framework: Integrative Planning

While data and analysis are critical elements in informed, ecosystem-based decision making, so too are the stakeholder processes that provide a framework for integrative planning. The I-70 Eco-Logical Project built upon the existing CSS process and, specifically, the ALIVE committee. A complete list of ALIVE committee members and affiliations as of 2011 is available in *Appendix G*. The general project approach, tasks and outcomes were steered by the ALIVE agencies and stakeholders. In this way, the I-70 Eco-Logical Project advanced the development of mechanisms for integrating connectivity concerns into transportation planning for the I-70 Mountain Corridor, as outlined in the ALIVE Memorandum of Understanding (2008). These mechanisms are designed to facilitate early incorporation of terrestrial and aquatic connectivity in each life cycle phase of the planning process and improve predictability in the environmental review process. The five life cycle phases are: 1) corridor planning, 2) project development, 3) project design, 4) project construction, and 5) operations, maintenance and monitoring (Fig. 6)

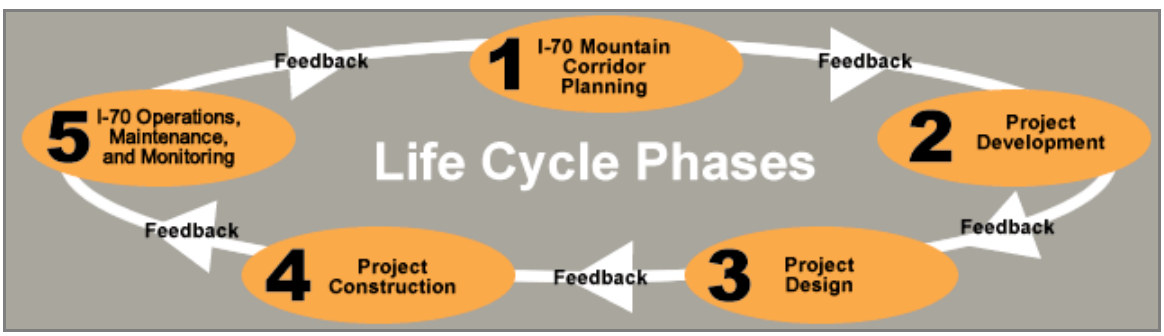


Figure 6: Five life cycle phases of a transportation project (CDOT 2011)

Regular meetings and email communication between the ALIVE committee and the project team, as well as sub-committee meetings provided the framework for advising, critiquing and revising the project components, among them the identification of the LIZs-2011 and the development of specific recommendations for meeting permeability goals within each of those zones. In addition, the project team worked closely with CDOT and the contractor for the CSS process (CH2M HILL) to integrate connectivity data and recommendations directly into the web-based CSS Guidance Manual (http://i70mtncorridorcss.com/), a one-stop shop for CDOT project managers and other members of planning and design teams to obtain pertinent information relating to a given highway segment. As a centralized information depot for the I-70 Mountain Corridor, the CSS website also provides mechanisms for holding the agency accountable to the core values agreed upon in the CSS process.

The CSS Guidance Manual includes standard design solutions, historic context, and decision making procedures to be used at each life cycle phase of project development, from planning and design through construction, operations, maintenance and monitoring. A 'Healthy Environment' is one of eight core values identified by stakeholders during the CSS process. The outcomes of the I-70 Eco-Logical Project directly inform the wildlife section of the CSS guidance for a Healthy Environment. The accessibility of terrestrial and aquatic GIS data and connectivity recommendations via the CSS map server ensures that this information is readily available to project teams at the outset of project scoping and can be applied as projects move from one life cycle phase to the next. Sidebars on the website provide easy access to key documents under the heading 'Must See, Must Do'. Included in this sidebar are links to the LIZ-2011 recommendations and the terrestrial and aquatic connectivity guidelines, as well as the ALIVE Implementation Matrix (Section 3.1). A second sidebar provides links to 'Nice to Know' information, including the I-70 Wildlife Watch website. The website is managed by CDOT and annual updates will be made to keep the site current with the latest information, data and tools.

3.1. ALIVE Implementation Matrix

To further support the objectives of 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 matrix was modeled after a similar matrix developed by the SWEEP committee to carry out the goals of their MOU.

The purpose of the ALIVE Implementation Matrix was to provide a framework for implementing the ALIVE MOU by giving additional structure and guidance in addressing connectivity concerns as projects on the Corridor move into Tier 2 planning. The 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. Over the course of six months the working group met and corresponded to develop a final draft Matrix, which was then reviewed and approved by the full ALIVE committee.

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 that are needed to improve, protect, or restore permeability for wildlife and important habitat components, as put forth in the ALIVE MOU (Table 4). As activities in the Corridor move from corridor planning to project development and 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 2011).

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). The ALIVE Implementation Matrix is also directly accessible to CDOT, resource agencies and other stakeholder groups via the CSS website.

While neither the CSS website nor the Implementation Matrix guarantee an integrative process, these are important tools to guide CDOT, the resource agencies, local communities, and other interested parties in balancing all of the Corridor values that may be affected by proposed Corridor projects. In this way, the CSS is an expression of CDOT's commitment to open and collaborative processes on the Corridor (P. Kozinski, CDOT, personal communication, Nov. 2010).

Stakeholder engagement for Tier 2 project planning will be in the form of Project Leadership Teams composed of CDOT and local representatives from each of the resource agencies, communities and stakeholder groups affected by the proposed project. These teams are not decision-making bodies, but a forum for open collaboration during project visioning and planning, with the ability to provide input as various alternatives are evaluated. The Leadership Teams may be advised by a Technical Team or Issues Task Force as needed (I-70 Mountain Corridor CSS 2010).

ALIVE and SWEEP committees are committed to continue holding annual meetings to evaluate performance and address upcoming projects that may fall outside of the purview of the Project Leadership Teams, such as the replacement of shoulder barriers or various maintenance projects that may offer opportunities to lessen barriers to wildlife movement outside of larger construction projects. These annual meetings also provide an opportunity for updating and amending the Implementation Matrix as needed to ensure its ongoing applicability and usefulness. 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.

Table 4. ALIVE Implementation Matrix

	Corridor Planning	Project Development	Project Design	Project Construction	Operations, Maintenance and Monitoring

WILDLIFE CONNECTIVITY AND HABITAT
 	
<u>Objective:</u>
To increase the permeability of the I-70 Corridor to terrestrial and aquatic species, including the 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. (MOU Purpose and Intent)
	<u>Inputs:</u>
	• Wildlife data
	• Land use information (incl. local land use, USFS management plans, BLM, etc.)
	• Ownership data (incl. private lands)
	• Existing LIZ and Eco-logical information and recommendations
	<u>Considerations</u>
	• What opportunities exist to improve, protect or restore permeability and habitat components?
	• How have wildlife habitat and populations changed since the original or last updated analyses?
	• What types of changes in wildlife habitat, populations or movements might occur in the reasonably foreseeable future?
	
	(continued on next page)
		<u>Inputs</u>
		• Target species movements and habitats
		• Wildlife guidelines and BMPs (I-70 Guidelines for Enhancing Wildlife Permeability)
		• Avoidance and mitigation strategies (I-70 Connectivity Recommendations)
		• Existing recovery efforts (USFWS/CDOW)
		• Coordination with CDOW, USFWS, USFS, BLM, local governments, other stakeholders
		<u>Considerations</u>
		• Are there permeability concerns outside of identified LIZs?
		• Where are there existing barriers to wildlife movement?
		• What opportunities exist to improve, protect or restore permeability and habitat components?
		
		(continued on next page)
			<u>Inputs</u>
			• Species specific needs and compatible project designs
			• Terms and conditions from Biological Opinion, if applicable
			<u>Considerations</u>
			• Will project designs improve or restore habitat and permeability?
			• Will project designs minimize impacts to habitat and permeability during construction?
			• Will project designs minimize impacts to habitat and permeability during operations and maintenance?
			
			(continued on next page)
				<u>Inputs</u>
				• Terms and conditions from Biological Opinion, if applicable
				• New species & habitat data since PS&E relative to all target species (or new target species) - NEPA re-evaluation
				<u>Considerations</u>
				• Are there unforeseen issues affecting habitat & permeability during construction?
				• Are there changes to the construction timeline that could affect habitat & permeability?
				<u>Outcomes and Products</u>
				• Mitigation modifications
					<u>Inputs</u>
					• Implementation and Monitoring Plan
					• Terms and conditions from Biological Opinion, if applicable
					<u>Considerations</u>
					• Are the mitigations successful relative to the permeability goals set during corridor planning and project development?
					  - What could be done differently?
					  - How could a structure be built better, cheaper next time?
					<u>Outcomes and Products</u>
					• Monitoring results
					• Lessons learned

	Corridor Planning	Project Development	Project Design	Project Construction	Operations, Maintenance and Monitoring
WILDLIFE CONNECTIVITY AND HABITAT (continued)	Outcomes and Products • Identify measurable permeability goals for the corridor • Avoidance strategies Mitigation strategies (I-70 Connectivity Recommendations) • Revised or refined LIZ information for that corridor segment (LIZs-2011) • Identify partnership and acquisition or easement opportunities (permanent protection opportunities for adjacent habitat)	Considerations (con't) • How have wildlife habitat and populations changed since the original or last updated analyses? • What types of changes in wildlife habitat, populations or movements might occur in the reasonably foreseeable future? • Do opportunities exist to enhance recovery efforts (e.g., approved Recovery Plans for ESA-listed species and State analog)? • Does the target species list include ESA-listed T&E species, species of state economic importance, USFS and BLM sensitive species, USFS MIS, & state spp. of concern? • Are there potentially conflicting mitigation/BMPs actions (crosswalk proposed mitigations) (continued on next page)	Considerations (con't) • Are there potentially conflicting mitigation/BMPs actions (crosswalk proposed mitigations) Outcomes and Products • Final Plan Specifications and Estimates (i.e., final designs) including specific mitigation measures • Monitoring plan, estimates and identified funding for monitoring & ongoing maintenance		

	Corridor Planning	Project Development	Project Design	Project Construction	Operations, Maintenance and Monitoring
		Outcomes and Products • Biological Evaluation (USFS sensitive spp.), Biological Assessment (USFS), Biological Opinion (USFWS), Biological Report (USFS) - Identify project-specific mitigation strategies relative to all target species - Establish commitment to monitoring			
INFORMATION NEEDS AND UPDATES Objective: Identify and acquire information needed to inform decision-making and outcomes at each life cycle phase.	• Changing and shifting habitats and wildlife populations • Ongoing LIZ revisions	• General and species-specific BMPs	• Species-specific and site-specific monitoring needs – what protocols should be implemented to evaluate the functionality of mitigation measures?	• Surveys prior to implementation	• Are there new or improved monitoring techniques which could provide greater efficiency and effectiveness in monitoring?

CHAPTER 4

Implementing a Regional Ecosystem Framework on the I-70 Mountain Corridor

Integrative planning provides a necessary foundation for CDOT and Corridor stakeholders in implementing an ecosystem approach, but these processes alone cannot ensure success at each level of planning. Several additional resources have been compiled as part of the I-70 Eco-Logical Project to support implementation as connectivity mitigations are incorporated into each sequential step of Tier 2 project planning. Small successes can be built early by incorporating low cost enhancement opportunities throughout the Corridor, leveraging other opportunities and complementing the construction of new wildlife crossing structures (Section 4.1). Performance measures prompting project planners with questions and laying out milestones help gauge progress and determine success at each step of project planning and implementation (Section 4.2). Pre- and post-construction monitoring is essential to measuring the effectiveness of new and retrofitted structures, directing adaptive management needs and informing future mitigation designs for the greatest cost-efficiency and effectiveness for wildlife passage.

4.1. Early Enhancement Opportunities

Through the roadway inventory, the researchers were able to evaluate existing bridges and culverts relative to their functionality as potential wildlife crossings. While in some cases the existing structure must be replaced with a new structure to accommodate the target wildlife in an area, in others, the existing structure may be modified to better accommodate wildlife passage (Kintsch and Cramer 2011). In developing the full suite of mitigation recommendations for road-stream crossings and LIZs-2011 in the Corridor, wherever possible, the researchers highlighted opportunities for such improvements to the existing infrastructure.

These 'early enhancement opportunities' are low-cost measures that can be conducted outside of projects and have the potential to improve the functionality of an existing structure for passage by some or all of the target species in an area. Early enhancement opportunities may include maintenance activities, retrofits to existing structures, or the addition of guide fencing at an existing bridge or culvert. By identifying where early enhancement opportunities are feasible along the Corridor, small connectivity improvements can move forward without having to wait for major infrastructure projects to commence. Consequently, implementing early enhancement opportunities are excellent mechanisms for building success early through small projects and demonstrating efficient use of transportation dollars to reduce AVCs and improve landscape permeability for wildlife.

Implementing these types of improvements does not preclude the need for new wildlife crossing structures within the Corridor. Retrofit measures and other enhancements complement other mitigation solutions within each of the LIZs-2011. Ultimately, achieving permeability within a LIZ requires multiple safe passage opportunities, depending on the length of the roadway segment in question. Summary lists of early enhancement opportunities for terrestrial wildlife passage and fish passage are provided in Tables 5 and 6, respectively. Other locations also suitable for wildlife enhancements may also be present outside of the defined LIZs-2011, and these should be also considered as opportunities arise to promote corridor-wide permeability.

Table 5. Summary list of Early Enhancement Opportunities for terrestrial wildlife passage in LIZs-2011. For sites where the Early Enhancement Opportunity is listed as a 'Minimum Recommendation', these should be considered alternatives that can be implemented immediately if the Preferred Recommendation cannot be implemented until sometime in the future. For complete site descriptions and recommendations see the document *I-70 Connectivity Recommendations* in *Appendix E* or available on the I-70 Mountain Corridor CSS website. Photographs of each location are available in the Access database accompanying this report.

Milepost	Loc. #	LIZ-2011	Early Enhancement Opportunity
152.6	JP126	B: Wolcott West	Move wildlife fencing to run over the top of the pipe rather than running in front of structure entrances. Add small mammal fencing to connect structures under EB and WB lanes through open median. Remove accumulated sediment limiting through-passage.
154.0	JP116	B: Wolcott West	Divided bridge. Widen and improve dry pathway between river and Hwy 6 on east side of structure by moving guardrail closer to road and maintaining a dirt/gravel pathway through large boulders lining the river bank. Replace or cover gabian wall abutment with natural substrate. Implement measures to minimize human activity on north side of Eagle River to encourage wildlife use.
158.7	JP114	D: Wolcott East	Divided bridge. Replace concrete abutments with natural slopes. Connect existing wildlife fencing completely to structure so that there are no gaps. Traffic on Hwy 6 may preclude some wildlife movement, but large span offers large area for wildlife to traverse. Minimize human access on non-roaded side of river to encourage wildlife passage.

Milepost	Loc. #	LIZ-2011	Early Enhancement Opportunity
170	JP048	E: Dowds Junction	Minimum Recommendation: Remove & restore dirt parking area in front of south entrance of box culvert and prevent cars/trucks from driving through the structure. Divert trail users to park on the north end of the structure. Add sediment baffles and maintain sediment pathway through the structure. Restore vegetation around south side entrance and add wildlife crossing warning signs and rumble strips to Hwy 6 at the north entrance. Animals are naturally funneled below the hwy level at this location; fencing may not be necessary, although this question requires further investigation. In lieu of fencing, consider adding a concrete shoulder barrier to the north side of the highway, extending beyond where the drainage reaches the same level as the roadway.
171.1	JP047	E: Dowds Junction	Construct dry, flat pathways (>3' wide) through the riprap slopes on both sides of the river and connecting to the adjacent habitat. Restore natural stream banks through the structure and leading under the adjacent bridge to north.
171.3	JP046	E: Dowds Junction	Minimum Recommendation: Construct dry, flat pathways (≥3' wide) through the riprap abutments on both sides of the river connecting to adjacent habitat.
177.4	JP149	F: Vail (East)	Open up bridge and naturalize side slopes; add dirt or vegetated pathway. Sign at-grade crossing over parallel frontage road (stop signs at intersection keep traffic speeds low at this location)
182	JP063	G: Gore Creek	Concentrate human activity immediately around paved access road at west end of bridge and implement measures to minimize human activity beneath the rest of the structure. Restore dirt lot/road with native vegetation cover. Requires coordination with local community and user groups to implement effective control measures and to educate the public on the importance of segregated wildlife/human uses at this location.
183.0	JP061	H: West Vail Pass	Remove culvert and restore stream channel through bridge structure. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings. If the roadway footprint increases with future highway reconstruction, the span and height of the bridge should also be increased to compensate for the additional length that animals must travel under the bridge.
184.0	JP096	H: West Vail Pass	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.
184.5	JP060	H: West Vail Pass	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.

Milepost	Loc. #	LIZ-2011	Early Enhancement Opportunity
185.0	JP059	H: West Vail Pass	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.
185.5	JP058	H: West Vail Pass	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.
218.5	JP079	M: Bakerville	Improve wildlife passage at existing bridge structure by opening up a natural substrate pathway adjacent to the roadway to encourage nighttime use of the structure. Add signage to inform drivers of potential wildlife activity (interchange traffic is slow moving and required to stop around this structure).
225.0	JP075	M: Bakerville	Open up and naturalize side slopes and road shoulders to encourage nighttime wildlife use.
223.5	JP102	M: Bakerville	Convert one lane of the bridge to vegetative grass/shrub cover. Investigate adding an at-grade wildlife crosswalk over Highway 6 at this location or other mechanisms to slow traffic and make drivers aware of potential wildlife crossing. Install guide fencing to direct animals away from the highway and towards the structure.
249.0	JP041	P: Beaver Brook	Minimum recommendation: open up riprap side slopes of bridge structure and restore vegetative cover along edges of road. Ultimately, replace structure with a more expansive bridge also spanning Soda Creek and restore riparian zone through structure (JP041). Add wildlife fencing (and amphibian walls) to guide animals to structure.
253.4	JP097	Q: Mt Vernon Creek	Minimum recommendation: Set back park fencing and add gates leading to box culvert so that they can be closed when moving the bison herd from one side of the highway to the other and left open for wildlife passage the rest of the time. Discourage cars parking above culvert on south side of interstate for bison viewing - direct all tourist traffic to north side viewing area, away from culvert. Note: adjusting the bison enclosure will allow wildlife access to the culvert, however this culvert is not considered large enough for elk passage. It is possible, though uncertain, that the resident herd could become adapted to it, particularly given the high traffic levels on I-70. Coordinate with Denver Parks on fence design and maintain viewing area on NE side (off exit)

Table 6. Summary list of Early Enhancement Opportunities for fish passage. For sites where the Early Enhancement Opportunity is listed as a 'Minimum Recommendation', these should be considered alternatives that can be implemented immediately if the Preferred Recommendation cannot be implemented until sometime in the future. Starred locations are streams where target species presence is unknown and should be confirmed with CDOW before implementing enhancements. For complete site descriptions and recommendations see the document *I-70 Connectivity Recommendations* in *Appendix E* or available on the I-70 Mountain Corridor CSS website. Photographs of each location are available in the Access database accompanying this report.

Stream Name	Milepost	Loc. #	Early Enhancement Opportunity
Buck Creek*	164.3	JP138	Build up grade coming into inlet so that water flow doesn't have to 'jump' into culvert. Add substrate inside culvert and secure by constructing baffles or weir plates inside the culvert.
Unknown Tributary to Gore Creek	172.9	JP139	Replace culvert with an oversized box, arch or pipe so that the outlet invert is at the elevation of Gore Creek at low flow. Reroute wildlife fencing so that it does not block culvert inlet.
Buffehr Creek*	174.0	JP095	Improve transition into culvert by creating a step-pool system through culvert, including a low-flow channel. Consider downstream improvements such as rock weirs.
Red Sandstone Creek	175.0	JP094	Add rocky step-pool system through culvert and at inlet to control high water velocities and provide resting areas inside the culvert. Include a low-flow channel in the retrofit design. Ultimately, install a new, larger culvert (e.g., oversized open bottomed pipe) more consistent with the natural stream channel slope and alignment. Restore natural stream channel and maintain natural substrate through the new culvert.
Bighorn Creek*	180.6	JP090	Remove barrier at inlet and allow substrate to fill the bottom of the culvert and restore natural grade into inlet. Ultimately, replace culvert with large 3-sided box, arch, open-bottomed pipe or embedded pipe culvert. Maintain a grade through the culvert that is consistent with upstream and downstream conditions. Construct features to mimic channel conditions through the culvert and improve fish passage. Coordinate with local municipality to ensure continued connectivity through downstream culvert.
Unknown Tributary to Black Gore Creek	183.0	JP135	Remove culvert and restore stream channel under bridge structure at same location (JP061)
Unknown Tributary to Black Gore Creek	183.3	JP134	Install shallow weir plates through culvert to reduce water velocities and add roughness. Ultimately, install a new, larger culvert (e.g., oversized open bottomed pipe) to encompass the channel's bankfull width. Construct features that mimic channel conditions through the culvert and improve fish passage.
Unknown Tributary West Tenmile Creek*	191.2 (EB)	JP030	Repair crushed flared end section at inlet. Install weir plates and add gravel substrate inside culvert; construct step/pool features at outlet.

Stream Name	Milepost	Loc. #	Early Enhancement Opportunity
Unknown Tributary West Tenmile Creek*	191.5	JP127	Construct drop/pool structures.
Unknown Tributary to West Tenmile Creek*	192.0	JP032	Install weir plates at inlet and through structure to control flow velocities and retain gravel substrate.
Unknown Tributary to West Tenmile Creek*	193.0 (WB)	JP056	Narrow channel at inlet to create deeper pool and increase flow depth over inlet apron. Coordinate terrestrial and aquatic connectivity needs and, ultimately, remove fill and construct a large bridge or arch underpass. Restore natural hydrologic flow regime.
Salt Lick Gulch*	204.5	JP039	Coordinate with CDOW to determine priority, given lack of connectivity downstream to Blue River at culvert under access road. Construct a series of drop/pools at the outlet to remove drop.
Herman Gulch	218.5	JP078	Minimum recommendation: add weir plates on inlet apron to create drop-pool structure. May add weir plates through structure as well. Maintain step pools at outlet.
Silver Gulch*	228.2	JP065	Remove drop at frontage road by cutting back the culvert and creating a step/pool system. Ultimately, replace and lower the culvert.
Soda Creek*	249.0	JP041	Minimum recommendation: replace with a bottomless culvert and construct step/pool structures to eliminate drops.
Mt Vernon Creek*	256.0	JP001	Reduce the width to depth ratio and install habitat enhancement measures, such as adding weirs at inlet and through culvert to provide velocity control and a low-flow channel through the culvert. Identify water rights holder and determine if water diversion in use; if possible, remove water diversion at outlet.

4.2. Performance Measures

It is commonly stated that success must first be defined to know when it has been achieved. Performance measures serve as a yardstick for evaluating success and are an important component of the ecosystem approach, where each cycle is strengthened by the knowledge gained from the successes and failures of the previous cycle (Bacher-Gresock and Schwarzer 2009).

Performance measures for the I-70 Eco-Logical Project were developed as measures of success towards the overall goals of increased streamlining and predictability in environmental review and enhanced connectivity for terrestrial and aquatic wildlife. Table 7 outlines specific performance measures at both the Corridor level and the project level. These performance measures ask specific questions and provide milestones for gauging progress.

Table 7. Performance measures for evaluating connectivity projects and procedures in the I-70 Mountain Corridor.

Performance Measures for the I-70 Mountain Corridor			
Objective	**Considerations**	**Monitoring Technique**	**Milestones**
Stakeholder engagement and predictability in environmental review processes	Has the REF provided for increased predictability and fewer 'surprises' at the project level to CDOT or the resource agencies and other stakeholders?	Review environmental review processes	o Project delivery on time and incorporating connectivity recommendations and guidelines
	Are resource agencies and other stakeholders contributing their data, information, plans and concerns into the project development process as outlined in the ALIVE Implementation Matrix? Does the matrix need any revisions to address additional needs or concerns?	Review projects at each life cycle phase. Assess whether appropriate information being utilized.	o Annual ALIVE and SWEEP meetings and adherence to project life cycle inputs, considerations and outputs as outlined in the Implementation Matrices
Transparency in each life cycle phase of the transportation planning process	Are stakeholders engaging in the Project Leadership Teams and holding CDOT accountable for stakeholder-identified values within a project area?	Review PLT processes and survey PLT members for their satisfaction with the process	o Regular quarterly updates to stakeholders from CDOT. o PLT process initiated and stakeholders engaged in and contributing to the project development process.

Enhanced connectivity for all target species throughout the Corridor	Are the connectivity recommendations for each LIZ being implemented?	Review progress towards connectivity goals and recommendations within each LIZ	o Goal of 'one new wildlife crossing structure per LIZ' met o Early Action Opportunities implemented
	Are the connectivity guidelines being used to inform projects regardless of whether they are in a LIZ?	Review projects to ensure progress towards Corridor-wide connectivity goals	o All projects in Corridor adhere to connectivity guidelines, as appropriate o Connectivity guidelines updated as new information becomes available about 'what works'
Performance Measures within Each LIZ-2011			
Objective	**Monitoring Considerations**	**Monitoring Technique**	**Milestones**
Terrestrial and aquatic connectivity needs fully integrated into each life cycle phase of a project (Implementation Monitoring)	Have target species been identified and connectivity needs assessed at the outset of project visioning?	Review of project vision before moving into project design phase	o Project vision incorporating connectivity needs and guidelines. o Pre-construction monitoring conducted to inform project vision and design
	Are target species needs and site-specific features informing project design?	Review of project design before moving into construction phase	o Project designs include appropriate connectivity measures for each of the target species
	Have construction BMPs been identified?	Site visits during construction and upon completion	o Construction BMPs implemented o Structure was installed or retrofit as designed

	Have monitoring objectives been identified and a monitoring plan developed?	Review of monitoring plans before project wrap-up	o Structure being monitored for effectiveness and functionality for the target species
	Is there a framework for supporting ongoing maintenance and implementing adaptive management as needed?	Annual maintenance checks and assessments of adaptive management needs based on effectiveness and implementation monitoring results	o Maintenance needs incorporated into projects o Adaptive management measures implemented, as needed
Structures are performing as intended over the long-term (Effectiveness Monitoring)	Are the passage design features (e.g., sediment baffles, pathways, weirs, etc) holding up over time? Are crossing structures, other wildlife fencing and passage features functioning as intended even under heavy snowpack conditions?	Annual checks (more frequent if needed)	o Project design holding up over time with little or no additional maintenance o Design for future projects modified as needed based on monitoring results
Target species are moving through passages as intended (Validation Monitoring)	Is the structure meeting species passage goals? Have any unintended consequences arisen as a result of the project (e.g. unplanned for passage use by humans)? Have animal-vehicle collisions decreased?	Carefully designed before and after research studies to determine passage and repel rates and/or genetic connectivity; AVC rates; etc.	o Passage goals met or exceeded (may require at least 3-10 years of monitoring to detect) o Adaptive management implemented as needed to meet passage goals

4.2.1. Wildlife Monitoring

Wildlife monitoring is a critical component in evaluating whether wildlife connectivity mitigation measures are performing as intended. Monitoring research across North America is continually feeding the knowledgebase informing the construction and design of effective wildlife crossing structures (Cramer and Bissonette 2005), yet each site is unique and planners cannot rely solely on the lessons learned at other locations. Careful observations, a growing understanding of animal behavior and sensory perception, and trial-and-error – through monitoring, research and adaptive management – are essential processes in the design and construction of functional wildlife crossings. Such trials are particularly important in evaluating innovative new structure designs and other mitigation strategies.

Ideally, all new and retrofitted crossing structures from the smallest pipe to the largest wildlife overpass should be monitored for their effectiveness for the benefit of future mitigations and maximum cost-effectiveness. Both pre- and post-construction monitoring are needed to evaluate the effectiveness of a crossing structure and to enhance an understanding of how wildlife respond to a given mitigation measure. A Before-After, Control-Impact study design offers a rigorous experimental design for evaluating pre- and post-construction impacts, but may be difficult to execute given the requirements for randomization and replication (Hardy et al 2007).

Pre-construction monitoring information should be gathered for a minimum of one to three years and includes the collection of baseline data on the variety of species that are present in the project area and seasonal variations in use. These pre-construction data can help answer questions about habitat and roadway features that influence animal movements (Montana Department of Transportation 2002), and inform project designs for maximum efficacy before construction begins.

Post-construction monitoring is essential for evaluating success, which can drive support for additional projects; informing the design of new crossing structures; and determining adaptive management needs. Post-construction monitoring activities should be conducted for a minimum of two years and, ideally, for three or more years over all seasons. Research has demonstrated that there is often a lag period as species become accustomed to a new crossing structure (Clevenger and Waltho 2003, Dodd et al 2009). Monitoring activities in Banff demonstrated that deer usage of the wildlife crossing structures continued to increase over a five-year period, while elk usage leveled off, and even decreased slightly in the fifth year (Clevenger and Waltho 2003). These trends in usage are only discernable in a program that is dedicated to monitoring usage over multiple years, and must be considered with regards to other annual trends and patterns of use influencing population demographics. The population-level effects of a new barrier or mitigation of an existing barrier may take several generations to be observed, especially for wide-ranging species that occur in relatively low densities and have low reproductive rates (Clevenger et al 2002*a*).

Monitoring objectives must be clearly defined from the outset; these objectives will then guide what data needs to be collected and which techniques should be used (USFS 2008). A variety of monitoring techniques are available requiring varying levels of investment in time and equipment (see Resources Box below). These techniques include track beds, cameras and video monitoring; collaring representative members of a population; and DNA analysis of hair or scat. Motion-triggered cameras are commonly used in a number of studies, including this one, as a cost-effective means for detecting species presence and determining passage rates (e.g., Cramer 2011, Cramer et al 2011*a*). Bonaker (2008) cautions that multiple monitoring techniques are best used in conjunction as one technique is likely to capture species activity that another technique misses.

Select Resources for Monitoring the Effectiveness of Wildlife Crossing Structures

Monitoring Crossing Structures for Terrestrial Wildlife

- Clevenger, A. P. and M. P. Huijser. 2011. Wildlife crossing structure handbook: design and evaluation in North America. Report to the Federal Highway Administration. Publication No. FHWA-CFL/TD-11-003. Western Transportation Institute, Bozeman, Montana.
    - See Chapter 5: Monitoring Techniques, Data Interpretation and Evaluations
    - http://www.cflhd.gov/programs/techDevelopment/wildlife/

Monitoring Road-Stream Crossings for Fish Passage

- Harris, R. R. 2005. Monitoring the effectiveness of culvert fish passage restoration – Final Report. Center for Forestry, University of California. Berkeley, CA.
    - http://forestry.berkeley.edu/comp_proj/DFG/Monitoring%20the%20Effectiveness%20of%20Culvert%20Fish%20Passage%20Restora.pdf

Effectiveness monitoring is an integral component of adaptive management, which allows adjustments to be made to management actions based on monitoring results. The science and practice of wildlife crossings is still an emerging field, and the principles of adaptive management are essential in ensuring that each new mitigation measure benefits from all previous efforts, both successful and unsuccessful. In turn, each new location with monitored mitigations contributes to the growing knowledgebase, helping conservationists, natural resource managers and transportation engineers alike determine what works, for which species, and where. Historically, a lack of available information on the effectiveness of various mitigation measures (Romin and Bissonette 1996) and wildlife data has significantly hampered the construction of effective wildlife crossings. But this trend is changing as evidenced by ongoing efforts in Canada (Clevenger et al 2002*a*), Montana (Hardy et al 2007), Arizona (Dodd et al 2009) and elsewhere.

No mitigation measure is likely to achieve one-hundred percent effectiveness (measured as proportion of successful crossing and/or decrease in animal-vehicle collisions), nor is such an accomplishment necessary for success (Hardy et al 2007). Yet a well-conceived monitoring and adaptive management strategy is an essential component of designing and implementing mitigation measures for wildlife to ensure their greatest functionality possible.

In addition to the overall contributions to the science and practice of road ecology, long-term monitoring offers project-specific benefits that can help prevent the need for costly retrofits in the future, while helping to fine-tune mitigation measures through adaptive management (Ruediger and DiGiorgio 2007). Monitoring new mitigation strategies and experimental designs provides crucial information for DOTs determining whether such strategies may be replicated elsewhere. Finally, the evidence provided by monitoring efforts on the effectiveness of mitigation measures is an important tool in maintaining agency and public support for wildlife crossings (Clevenger and McGuire 2001; Ruediger and DiGiorgio 2007).

4.3. Conclusion

CDOT's commitment to collaborative planning for the I-70 Mountain Corridor presented a unique opportunity to implement a Regional Ecosystem Framework. The I-70 Eco-Logical Project is a systems level approach to strategic mitigation planning for the purpose of guiding project-level planning as CDOT embarks on the next stage of planning, design and construction on the Corridor. An assessment of wildlife priorities and mitigation options combined with agreed-upon stakeholder processes can expedite environmental review by fulfilling regulatory obligations in advance of final design and construction, removing potential 'surprises' in the review process for all agencies (Hardy and Wambach 2009)

The 17 identified LIZs-2011 and aquatic connectivity locations reflect the current 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, agencies 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, the resources contained therein may also be accessed for the purpose of compatible public land management or county zoning and transportation planning.

The I-70 Eco-Logical Project 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. In this way, the I-70 Eco-Logical Project framework makes it easier to go above and beyond regulatory requirements in protecting and restoring connectivity for wildlife while addressing the substantial infrastructure and congestion challenges present in the Corridor. I-70 was originally constructed without the benefit of an ecosystems approach. Rather than attempting to mitigate the impacts of additional infrastructure on a project-by-project basis, the I-70 Regional Ecosystem Framework now offers strategic guidance for improving connectivity and diminishing the barrier effect along the I-70 Mountain Corridor.

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APPENDIX A: Target Species

TERRESTRIAL TARGET SPECIES				Bioregion					
Species Guild	**Common Name***	**Scientific Name**	**Home Range Size**	**Western Slope Foothills (6,000-7600 ft)**	**Western Slope Montane (7,600-9,000 ft)**	**Subalpine (9,000-11,400 ft)**	**Alpine (> 11,400 ft)**	**Eastern Slope Montane (7,600-9,000 ft)**	**Eastern Slope Foothills (6,000-7600 ft)**
Low Mobility Fauna	Northern Leopard Frog	*Rana pipiens*	< 0.5 mi movements between ponds/ hibernacula	x	x	x		x	x
	Boreal Toad	*Bufo boreas*	< 0.5 mi movements between ponds/ hibernacula		x	x			
	Greater sage grouse	*Centrocercus urophasianus*		x	x			x	x
	White-tailed ptarmigan	*Lagopus leucurus*			x	x	x	x	
Mobile Small Fauna	Midget faded rattlesnake	*Crotalus oreganos concolor*	< 1 mile	x					
	Common garter snake	*Thamnophis sirtalis*	.01 sq mi						x
	Preble's meadow jumping mouse	*Zapus hudsonius preblei*	0.0003 sq mi	x					x
	White-tailed prarie dog	*Cynomys leucurus*	0.023 sq mi	x	x			x	x
	Pygmy shrew	*Sorex hoyi montanus*				x	x		
	American Marten	*Martes americana*	0.3 sq mi			x	x		
	River otter	*Lontra canadensis*	1.2 mi (along a river); mean HR is 20 mi long	x	x	x			
	Red Fox	*Vulpes vulpes*	up to 23 sq mi (2 sq mi in urban areas)	x	x	x	x	x	x

APPENDIX A: Target Species

				Bioregion					
Species Guild	**Common Name***	**Scientific Name**	**Home Range Size**	**Western Slope Foothills (6,000-7600 ft)**	**Western Slope Montane (7,600-9,000 ft)**	**Subalpine (9,000-11,400 ft)**	**Alpine (> 11,400 ft)**	**Eastern Slope Montane (7,600-9,000 ft)**	**Eastern Slope Foothills (6,000-7600 ft)**
Highly Mobile Adaptive Fauna	Coyote	*Canis latrans*	4 sq mi (mean)	x	x	x	x	x	x
	Black Bear	*Ursus americanus*	14 sq mi (resident females)	x	x	x		x	x
	Canada Lynx	*Lynx canadensis*	28 sq mi (females)		x	x		x	
	Bobcat	*Lynx rufus*	3 sq mi (females)	x	x			x	x
High Mobile High Openess Large Fauna	Mountain Lion	*Felis concolor*	15 sq mi (females)	x	x	x	x	x	x
Adaptive Ungulates	Moose	*Alces alces*	2 sq mi	x	x	x		x	x
	Mule Deer	*Odocoileus hemionus*	< 1 sq mi seasonally with up to 60+ mile migrations between summer and winter range.	x	x	x		x	x
Very High Openness Fauna	Bighorn Sheep	*Ovis canadensis*	3 mile seasonal movements		x	x	x	x	
	Elk	*Cervus elaphus*	4 km (migration for non-resident herds)	x	x	x		x	x

APPENDIX A: Target Species

AQUATIC TARGET SPECIES

Common Name	Scientific Name	Conservation Status	Watershed
All aquatic macroinvertebrates	*all spp.*	***USFSMIS***	
Bluehead sucker	*Catostomus discobolus*	***USFSSS, USFSMIS, FWS Candidate Species***	***Colorado River***
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*	***USFSSS, USFSMIS***	***Colorado River, Eagle River, Blue River***
Flannelmouth sucker	*Catostomus latipinnis*	***USFSSS, USFSMIS, FWS Species of Concern***	***Colorado River***
Greenback cutthroat trout	*Oncorhynchus clarki stomias*	***FT, USFSMIS***	***Clear Creek***
Lake chub	*Couesius plumbeus*	***USFSSS***	***Clear Creek***
Mountain sucker	*Catostomus platyrhynchus*	***USFSSS***	***Colorado River***
Roundtail chub	*Gila robusta*	***Candidate species***	
Sculpin	*Various spp.*		

APPENDIX B: Species Movement Guilds (Kintsch & Cramer 2011)

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Attributes	Preferred Structures
Low Mobility Small Fauna (LMSF)	Invertebrates, frogs, toads, some salamanders, some ground insects	Small, slow-moving species that require specific ambient conditions (including possibly moisture and light) to survive and disperse. Some species in this group may take several generations to move across a structure. Completely enclosed structures may interfere with directional movements for some species that navigate by reference to celestial features.	Crossings must provide species-specific habitat and consistent outside environmental conditions throughout the entire structure, including natural substrate, light, temperature and moisture. Species in this category may be found adjacent to water, but probably prefer dry pathways or pathways without flowing water through culverts.	*Extensive bridges, wildlife overpasses, trench drains*
Moderate Mobility Small Fauna (MMSF)	Ground squirrels, shrews, rabbit, hare, chipmunk, vole, mice, skunk, raccoon, some salamanders, lizards, turtles, snakes, badger, marmot, weasel, pika, fox, marten, fisher, river otter, beaver, mink, muskrat, some ground birds	Small animals that are fairly adaptable to different types and sizes of structures. Almost all of these species are prey for larger species and require some hiding cover for protection. Some may require a natural substrate or moisture to survive in structures, and most prefer natural substrates.	Functional crossing structures include a variety of structure types and sizes. A non-submerged pathway is almost always preferred and usually required by species in this guild. They may also use structures with artificial substrate or ramps. Cover provided within larger structures with rocks, vegetation or smaller pipes is usable.	*Small, medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
Adaptive High Mobility Fauna (AHMF)	Black bear, bobcat, coyote, lynx	Medium-sized mammals that naturally use enclosed spaces for dens, and can tolerate a limited amount of enclosure in underpasses. Minimum crossing structure size is proportional to species body size.	Species in this group may use a variety of structure types and prefer to have suitable habitat directly adjacent to the structure entrances.	*Small, medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
High Openness High Mobility Carnivores (HOHMC)	Grizzly bear, mountain lion, wolf	Highly mobile species that prefer good visibility. Typically larger animals that have a larger minimum structure size requirement than Adaptive High Mobility Fauna. These species range widely across the landscape and may need to cross multiple highways.	Open structures that provide good visibility but can be tolerant of longer structures (>100'). Species in this group tend to prefer more open structures than Adaptive High Mobility Fauna but are more tolerant of enclosed structures than Very High Openness Fauna.	*Large bridge underpasses, extensive bridges, wildlife overpasses*

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Attributes	Preferred Structures
Adaptive Ungulates (AU)	Mule and white-tailed deer, moose, mountain goat	Medium and large-sized ungulates that require good visibility on a horizontal plane and a moderate amount of cover. These animals prefer a natural substrate and adjacent cover, but may also use concrete-bottomed culverts. Ungulates in this group use structures in approximate proportion to their body size (i.e., deer can use smaller structures than moose).	Passages that have good visibility within and around the structure and clear lines of sight from one end of a crossing structure to the other. Preferred structures are wider than they are tall and are less than 100' in length. Mule deer may prefer more open structures than white-tailed deer.	*Medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
Very High Openness Fauna (VHOF)	Elk, pronghorn, bighorn sheep, open habitat grouse	Ungulates in this group are particularly wary of predators and require very wide vistas and clear lines of sight. They tend to prefer a moderate amount of hiding cover that does not infringe on their ability to detect or escape predators. Structure size is dictated primarily life history attributes such as predator avoidance or maneuverability.	Large passages with wide openings (at least 15') that are less than 100' long, excellent visibility within and around the structure, and clear lines of sight from one end of a crossing structure to the other. Bridge underpass structures with natural earthen side slopes are preferred to those with concrete or metal walls. Features that may encourage passage include a natural substrate, and noise and light contrast moderating features.	*Large culvert or bridge underpasses, extensive bridges, wildlife overpasses*
Arboreal Fauna (ArbF)	Flying squirrels, some bats, arboreal voles	Species that move primarily through the canopy rather than on the ground surface.	Features for these species provide a continuous canopy-level structure across the roadway.	*Treetop rope bridges, towers, or modified wire or metal structures.*
Aerial Fauna (AerF)	Songbirds, raptors, bats, flying insects (including butterflies)	Species whose primary mode of movement is flying.	Features for these species aim to divert flying species out of the path of traffic.	*Diversion poles, extensive bridges, wildlife overpasses*

APPENDIX C

Roadway Inventory Data Field Descriptions

The roadway inventory was conducted during the summer of 2009, with some follow-up in 2010 and 2011. All bridges and culverts one meter in diameter or larger found were inventoried. Fill slopes bisecting natural drainages and some potential at-grade crossing areas were also inventoried. Data was collected at 126 locations in total. This included 13 bridges, 27 divided bridges, 1 overpass, 26 concrete box culverts, 50 pipes, 13 fill slopes, and 5 at-grades.

Each site was assigned a unique identification number and its location was recorded using a hand-held GPS unit. For each location, two worksheets were filled out to record information on the site's terrestrial and road segment characteristics. Where appropriate, an additional worksheet was filled out to document aquatic features.

Terrestrial information
A worksheet was filled out for each inventoried location to document the terrestrial characteristics of the site. All structural dimension measurements are in meters and most were made using a 100-meter open reel measuring tape or a Nikon Forestry 550 Hypsometer Rangefinder. Large areas, such as the imprint of a fill slope or length of an at-grade, were measured by pacing. Some measurements, such as length of culverts, were unobtainable in the field. These measurements were estimated later using the ruler tool in Google Earth. Table 1 describes the variety of information collected on terrestrial characteristics at each location.

Table 1: Information collected on the Terrestrial Worksheet

LABEL	DESCRIPTION
Location ID	Unique ID for each location.
MP	Mile post for each location.
GPS ID	Unique ID recorded with a GPS unit usually the same as Location ID.
Situation	Situation type at location. Includes checkbox for structure, at-grade or fill.
STRUCTURE	**Information on structure situation types.**
Structure Type	If situation type is structure, then structure type at location. Includes checkbox for divided bridge, bridge, concrete box culvert, corrugated metal pipe, metal plate arch, other or pipe culvert.
Water	If present, water type at structure. Includes checkbox for perennial, ephemeral, wetland or none. If perennial or ephemeral water present, aquatic worksheet filled out.
% Terrestrial	Percent of structure available for terrestrial use at location. Documented by circling one of the following percentages: 0%, <10%, 10-25%, 26-50%, 51-75%, 76-100%.
Description 1	Describes to which side (north/south; inlet/outlet) structure measurements below refer. Noted on side.

Width 1	Width of structure as measured parallel to the roadway. Width 1 is measured from the inlet/outlet, north/south side of roadway, or for divided bridges, the east/westbound lanes of traffic. Terrestrial structures are measured from perspective of an animal moving through the structure.
Length 1	Length of structure as measured perpendicular to the roadway. For divided bridges, length 1 corresponds to either the east- or westbound lanes of traffic. Terrestrial structures are measured from perspective of an animal moving through the structure.
Height 1	Height of structure measured from the inlet/outlet, north/south side of roadway, or for divided bridges, the east/westbound lanes of traffic. For aquatic structures, height measured to water line where full structure height not measurable. Terrestrial structures are measured from perspective of an animal moving through the structure.
Diameter 1	Diameter of structure measured from inlet/outlet or north/south side of roadway.
Description 2	Describes to which side (north/south; inlet/outlet) structure measurements below refer. Noted on side.
Width 2	Width of structure as measured parallel to the roadway. If different, width 2 is measured from the inlet/outlet, north/south side of roadway or for divided bridges, the east/westbound lanes of traffic not measured for width 1. Terrestrial structures are measured from perspective of an animal moving through the structure.
Length 2	Length of structure as measured perpendicular to the roadway. For divided bridges, length 2 is measured from the east/westbound lanes of traffic not measured for length 1. Terrestrial structures are measured from perspective of an animal moving through the structure.
Height 2	If different, height of structure measured from the inlet/outlet, north/south side of roadway, or for divided bridges, the east/westbound lanes of traffic not measured for height 1. For aquatic structures, height measured to water line where full structure height not measurable. Terrestrial structures are measured from perspective of an animal moving through the structure.
Diameter 2	Diameter of structure measured from the inlet/outlet or north/south side not measured for diameter 1.
Skew from Road	Degree structure is skewed from roadway. If structure is a bridge, skew from road was recorded as 0. The road is the structure, so the structure cannot be skewed from road. However, the channel below the bridge may be skewed from road.
Substrate	Type of material on floor of structure. Includes checkbox for vegetation, dirt, concrete, water, bedrock or other.
Road	Type of road through structure. Includes checkbox for dirt, paved, private or none.
Human Use	Amount of human use at structure. Includes checkbox for light, moderate, heavy or none.
Use Type	Type of human use at structure. Includes checkbox for foot, horse, cattle, bicycle, motorized and/or other.

FILL SLOPE	Information on fill slope situation types.
Height	Height estimated as distance between the highest and lowest point of the fill slope.
Imprint	Length measured across the widest part of fill slope where it intersects th roadway
Side measured	North/south side of highway from which fill slope is measured noted by check box.
Describe	Detailed description of fill slope.
AT-GRADE	**Information on at-grade situation types.**
BMP	Mile post at which at-grade begins, measured to the nearest $1/10^{th}$ mile.
EMP	Mile post at which at-grade ends, measured to the nearest $1/10^{th}$ mile.
Length	Length measured across the widest part of at-grade that is parallel to the roadway.
Describe	Detailed description of at-grade.
GENERAL	**Information collected for all locations.**
Tracks	Animal tracks present at location. Checkbox provided for several species.
Scat	Animal scat present at location. Checkbox provided for several species.
Game trails	Description, including direction, of game trails present at location.
N - Vegetation	Vegetation present within 100 meters of north side of roadway. Includes checkbox for forest, grassland, shrub, riparian, pasture, bare ground, wetland and/or other.
S - Vegetation	Vegetation present within 100 meters of south side of roadway. Includes checkbox for forest, grassland, shrub, riparian, pasture, bare ground, wetland and/or other.
N Side < 1m high	Percentage of vegetation within 100 meters of north side of roadway that is less than 1 meter high. Percentage categories recorded as: 1 = 0%, 2 = < 10%, 3 = 10-25%, 4 = 26-50%, 5 = 51-75%, or 6 = 76-100%.
S Side < 1m high	Percentage of vegetation within 100 meters of south side of roadway that is less than 1 meter high. Percentage categories recorded as: 1 = 0%, 2 = < 10%, 3 = 10-25%, 4 = 26-50%, 5 = 51-75%, or 6 = 76-100%.
N Side > 1 m high	Percentage of vegetation within 100 meters of north side of roadway that is greater than 1 meter high. Percentage categories recorded as: 1 = 0%, 2 = < 10%, 3 = 10-25%, 4 = 26-50%, 5 = 51-75%, or 6 = 76-100%.
S Side > 1 m high	Percentage of vegetation within 100 meters of south side of roadway that is greater than 1 meter high. Percentage categories recorded as: 1 = 0%, 2 = < 10%, 3 = 10-25%, 4 = 26-50%, 5 = 51-75%, or 6 = 76-100%.
Structures	Structures, if any, present within 100 meters of north or south side of roadway. Side of roadway noted by check box. See Roadway Segment worksheet for information on type of structures present.
Open Water	Open water, if any, present within 100 meters of north or south side of roadway. Open water defined as greater than 10 meters wide and 1 meter deep as estimated by researcher. Side of roadway noted by check box.
N – Roadside Slope	Slope measured immediately adjacent to the end of the north side roadway shoulder. Measured in degrees.

S – Roadside Slope	Slope measured immediately adjacent to the end of the south side roadway shoulder. Measured in degrees.
N – Adjacent Slope	Slope measured approximately 10 meters out from the end of the north side roadway shoulder. Measured in degrees.
S – Adjacent Slope	Slope measured approximately 10 meters out from the end of the south side roadway shoulder. Measured in degrees.
WB In-Line Visibility	Estimated distance researchers could see looking both into and away from oncoming traffic when standing on shoulder for westbound lanes of traffic.
EB In-Line Visibility	Estimated distance researchers could see looking both into and away from oncoming traffic when standing on shoulder for eastbound lanes of traffic.
WB Visibility from 10m	Estimated distance researchers could see looking both into and away from oncoming traffic when standing 10 meters from shoulder for westbound lanes of traffic.
EB Visibility from 10m	Estimated distance researchers could see looking both into and away from oncoming traffic when standing 10 meters from shoulder for eastbound lanes of traffic.
Photo Points	Documentation of photo points taken in the field. In the least, includes photos from north and south side of roadway looking towards and away from the road.
General Comments	Additional information not captured in above documentation.

Road Segment information

A worksheet was filled out for each inventoried location to document the characteristics of the site within 1/10th mile on either side of the identified location. All measurements are in meters and most were made using a small tape measure or the Nikon Forestry 550 Hypsometer Rangefinder (Nikon, Inc., Melville, NY, USA). Table 2 describes the variety of information collected at each location.

Table 2: Information collected on the Road Segment Worksheet

Label	Description
Road Segment ID	Unique ID for each road segment.
Corresponding Location ID(s)	Location ID(s), as documented on the Terrestrial worksheet(s), for which the Road Segment worksheet is being completed.
Name/Landmark	Nearby landmark or name associated with location.
BMP	Mile post at which road segment begins 1/10th mile from the inventoried location.
BGPS	GPS point for segment beginning. Not documented for this project.
EMP	Mile post at which road segment ends 1/10th mile from the inventoried location.
EGPS	GPS point for segment end. Not documented for this project.

Road Footprint	Width of road as measured perpendicular to flow of traffic. Measurement includes both directions of traffic, and when appropriate, highway on/off-ramps, chain-up stations, etc.
Uneven Lanes	Documentation that east/westbound lanes are not even with the other noted by Y/N checkbox.
Frontage Road	Presence of frontage roads, if any, within 100 meters of north or south side of roadway. Side of roadway noted by checkbox.
Railroad	Presence of railroad, if any, within 100 meters of north or south side of roadway. Side of roadway noted by checkbox.
Buildings	Type of buildings present, if any, within 100 meters of north or south side of roadway. Includes checkbox for commercial, residential, barn and/or other. Side of roadway noted by circling N or S.
Segment Comments	Additional information about road segment not captured in above documentation.
WESTBOUND/EASTBOUND	**Information on east- and westbound lanes of traffic**
# Lanes	Number of lanes of traffic for either the east- or westbound direction of traffic.
Road Width	Width of road as measured perpendicular to flow of traffic. Measurement includes either the east- or westbound lanes of traffic, and when appropriate, highway on/off-ramps, chain-up stations, etc.
Climbing Lane	Presence of climbing lane for either the east- or westbound lanes of traffic noted by Y/N checkbox.
Shoulder Barrier Type	Type of shoulder barrier present, if any, in road segment for either the east- or westbound lanes of traffic. Includes checkbox for none, jersey wall, guard rail or wire fence.
Barrier Height	Height of barrier present measured at the tallest point of the barrier within the road segment.
Photo id	ID number for any photos of barriers taken.
Barrier Contiguous Through Segment	Documentation of whether the barrier continues through entire road segment noted by Y/N checkbox.
ROW Fencing	Presence of fencing, if any, within the right-of-way. Includes checkbox for 4-strand, 8’ wildlife fencing, chain link or sound wall.
Retaining Wall	Presence of retaining walls, if any, within 100 meters of roadway. Upslope or downslope noted by checkbox.
Slope Cut > 45°	Presence of a slope cut greater than 45 degrees within 100 meters of roadway noted by checkbox.
Slope Fill < 45°	Presence of a slope fill less than 45 degrees within 100 meters of roadway noted by checkbox.
Exit/Entrance	Presence of on/off-ramp within the road segment noted by marking Y/N.

Rest Areas	Presence of a rest area within the road segment noted by marking Y/N.
Pull Outs	Presence of a pull out within the road segment noted by marking Y/N.
Chain-up Station	Presence of chain-up station within the road segment noted by marking Y/N.
Roadway Lighting	Presence of roadway lighting within the road segment noted by marking Y/N.
Other	Additional items present within the road segment not documented above.
Photo ID	ID number for any photos taken of items in this section.
MEDIAN	**Information on the roadway median**
Median Width	Width of median as measured perpendicular to flow of traffic. Measurement begins at the end of the eastbound lanes of traffic and ends at westbound lanes (or vice versa depending from which side it is measured).
Median Barrier	Presence of barrier within the median noted by Y/N checkbox.
Undivided	**Information on undivided highway road segments.**
Barrier Type	Type of barrier present in median, if any. Includes checkbox for guard rail, jersey wall or wire fence.
Barrier Height	Height of barrier present measured at the tallest point of the barrier.
Photo id	ID number for any photos of barriers taken.
Divided	**Information on divided highway road segments.**
WB Barrier Type	Type of barrier present in median, if any, for westbound traffic lanes. Includes checkbox for guard rail, jersey wall or wire fence.
WB Barrier Height	Height of barrier present measured at the tallest point of the barrier.
Photo id	ID number for any photos of barriers taken.
EB Barrier Type	Type of barrier present in median, if any, for eastbound traffic lanes. Includes checkbox for guard rail, jersey wall or wire fence.
EB Barrier Height	Height of barrier present measured at the tallest point of the barrier.
Photo id	ID number for any photos of barriers taken.
Comments	Additional information about road segment not captured in above documentation.

Aquatic Information

An Aquatics worksheet was filled out for each inventoried location identified as having a structure with perennial or ephemeral water to document the aquatic characteristics of the site. All structural dimension measurements are in meters and most were made using a small tape measure or the Nikon Forestry 550 Hypsometer Rangefinder. In some cases, the lengths of culverts were unobtainable from the field. These measurements were estimated later using the measurement tool in Google Earth. Table 3 describes the variety of information collected at each location.

Table 3: Information collected on the Aquatics Worksheet

Label	Description
Location ID	Unique ID for each location. Same as Terrestrial worksheet.
MP	Mile post for each location.
GPS ID	Unique ID recorded with a GPS unit.
Stream Name	Name of stream, if known, flowing through structure.
Watershed	Name of watershed in which stream is found.
Shape	Shape of structure. Includes checkbox for bridge, box, pipe, flat-bottomed pipe or arch.
Material	Material on floor of structure or the material an animal experiences underfoot. If bottomless (e.g., bridge or 3-sided culvert), then 'natural' selected. Includes checkbox for corrugated metal, concrete, PVC, smooth metal, natural or other.
Culvert Skew from Stream Channel	Degree structure is skewed from the stream channel as it flows into/out of the structure at the inlet/outlet.
Inlet Elevation	Elevation at inlet. Not recorded for this project.
Culvert Length	Length of culvert as measured perpendicular to the roadway. See Terrestrial worksheet for additional measurements on non-culvert structures.
Outlet Elevation	Elevation at outlet. Not recorded for this project.
Continuity of Substrate through Culvert	Presence of substrate through majority of culvert noted by Y/N checkbox.
Baffles, Weirs, Other Internal Structures	Presence of internal structures noted by Y/N checkbox.
Debris in Culvert	Presence of debris within structure noted by Y/N checkbox.
Shallow Water/Bank Edge through Culvert	Presence of shallow water or bank edge through culvert noted by Y/N checkbox.
Riprap/Bank Armoring	Presence of riprap or bank armoring within structure noted by Y/N checkbox.
Water Flowing Under Culvert	Presence of water flowing under culvert instead of through noted by Y/N checkbox.
Fill Eroding	Documentation of fill erosion around structure noted by Y/N checkbox.

Inlet	Information on inlet of structure
Stream Level Classification	Classification of stream at inlet based on the Rosgen Classification Scheme (Rosgen 1994, Rosgen 1996).
Substrate	Type of substrate present at inlet. Includes checkbox for bedrock, boulders, cobble, gravel, sand and/or silt/clay.
Type	Characteristics of inlet. Includes checkbox for natural, mitered, wingwall, headwall, apron and/or other.
Pool	Presence, if any, of pooling water at inlet noted by Y/N checkbox.
Pool Size	Approximate length and width of pool if present at inlet.
Culvert Slope	Slope measured immediately at culvert inlet. Measured in degrees.
Channel Slope 10m from Inlet/Outlet	Slope measured approximately 10 meters out from inlet. Measured in degrees.
Trashrack/Screen	Presence, if any, of trashrack or screen at inlet noted by Y/N checkbox.
Debris Plugging Inlet	Presence of debris obstructing inlet noted by Y/N checkbox.
Ratio of Inlet Width to Channel Width	Ratio of structure width at inlet to channel width at inlet.
Photo Points	Documentation of photo points taken in the field. In the least, includes photos looking towards the inlet and away.
Comments	Additional information about inlet not captured in above documentation.
Outlet	**Information on inlet of structure**
Stream Level Classification	Classification of stream at outlet based on the Rosgen Classification Scheme (Rosgen 1994, Rosgen 1996).
Substrate	Type of substrate present at outlet. Includes checkbox for bedrock, boulders, cobble, gravel, sand and/or silt/clay.
Configuration	Characteristics of outlet. Includes checkbox for at grade, projecting, freefall into pool/riprap, cascade into riprap, apron and/or other.
Culvert Slope	Slope measured immediately at culvert outlet. Measured in degrees.
Channel Slope 10m from Inlet/Outlet	Slope measured approximately 10 meters out from outlet. Measured in degrees.
Drop	Presence, if any, of drop at outlet noted by checkbox.
Drop distance	Height of drop if present at outlet.
Pool	Presence, if any, of pooling water at outlet noted by Y/N checkbox.
Pool Size	Approximate length and width of pool if present at outlet.
Photo Points	Documentation of photo points taken in the field. In the least, includes photos looking towards the outlet and away.
Comments	Additional information about outlet not captured in above documentation.

Passage Evaluation	Assessment of the degree to which a crossing resembles the adjacent stream form and function. Evaluation made relative to connectivity function only. Includes checkbox for resembles natural channel, adequate, indeterminate or inadequate.
Multiple Structures at Site	Documentation of other structures at same site. Includes line for # of identical openings, # of different openings (with ID for additional worksheet filled out for different openings), or # overflow pipes.

Barriers Mapping

To map barriers throughout the corridor, we noted the presence of a barrier in the median or within 100 meters of the roadside for each 1/10th mile road segment in our study area. 1/10th mile road segments were defined by the starting point of a given 1/10th mile segment, such that, for example, MP 140 represents from 140 – 140.1 or MP 228.9 = 228.9 – 229.0. Barriers cataloged include natural barriers such as cliffs, sound walls, and retaining walls.

Driving both east and west through the study area, we manually noted whether a barrier was present for each 1/10th mile road segment on spreadsheet created for the task. For each 1/10th mile segment, we marked one of three columns on the spreadsheet: 'Up' 'Down' and 'No' to denote an upslope barrier, a downslope barrier or no barrier, respectively. An 'X' signified natural barriers, 'SW' meant soundwalls and 'RW' meant retaining walls. Following any mark with '(Median)' signified that the barrier existed in the median.

This information was then converted to GIS using a CDOT road layer split into 1 mile-long segments using milepost as the dividing point. This process relied on the CDOT milepost layer, which was compiled for an invasive weeds mapping project based on the physical roadside milepost signs. However, the weedsmilepost layer does not include points for a stretch of roadway near Evergreen. Instead, for this section, we used a different CDOT milepost layer derived from a calculation of mileposts in a GIS using a linear referencing system. These are not the actual physical milepost locations, but, in most cases, they lie within close proximity to the physical milepost locations and provided a suitable surrogate where the weeds-mileposts data was not available. In addition, in the Officer's Gulch section, the on the ground mileposts (MP 197-199) are not 1 mile apart (198-199 going westbound is > 1 mile; and 199-200 going westbound is < 1 mile). This section was mapped in the GIS using the weedsmilepost layer.

Once the roadway was divided into mile-long segments, these were further split into 1/10th mile segments using the divide tool in ArcGIS. The attributes for this new layer were then manually filled in to mirror what was noted in the field.

Wildlife Fencing

We mapped all wildlife fencing that has been installed in the corridor as of July 2011. Installed fencing currently occurs solely in the western portion of the study area. Mapping was done by driving east and west through the study area and taking a GPS point at each point where fencing begins and ends. This includes each time fencing terminated resulting in a gap such as at an on-ramp/off-ramp. We did not map each time the fencing starts and ends at a structure (i.e. bridge or culvert) with no resulting gap nor did we map when fencing ends in a cliff wall and starts up again a few tenths of a mile up the road. One-way deer gates and jump-outs have also not been mapped.

To create a GIS line layer, a CDOT road layer was split at each GPS point and each resulting line segment was defined as either fencing or not. Additional attributes for this layer include a description of the start and end point for each fencing segment and which side of the interstate the segment is found.

APPENDIX D

A Revised Analysis of Linkage Interference Zones for Terrestrial Wildlife Along the I-70 Mountain Corridor

September 2011

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INTRODUCTION

The I-70 Eco-logical Project is designed to field test the ecosystem approach developed by the Federal Highway Administration (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 ultimate objective of the project is to develop solutions for restoring and mitigating transportation impacts on wildlife habitat connectivity (including animal-vehicle collisions) for terrestrial and aquatic species in each bioregion along the I-70 Mountain Corridor from Golden (MP 258) to west of Dotsero (MP 130).

The scope of work is composed of five tasks:

1) Compile inventory data, spatial layers, and research studies on aquatic and terrestrial wildlife and their connectivity needs along the I-70 Mountain Corridor including a) validate and refine Linkage Interference Zones (LIZs), and b) identify aquatic connectivity zones.

2) Monitor wildlife use of existing culverts and activity along the roadway.

3) Conduct multi-agency and stakeholder meetings to establish and review work products.

4) Integrate conservation priorities into the transportation planning process for the I-70 Mountain Corridor.

5) Avoid, minimize and mitigate both current and future impacts by identifying and prioritizing methods to reduce impacts on an ecosystem scale, specifically by 1) identifying and prioritizing mitigation options, 2) identifying a process for implementing early action conservation measures, and 3) providing criteria for evaluating the conservation effectiveness of implemented measures.

This report outlines the methods for validating and refining the LIZs first mapped by the ALIVE Committee (CDOT 2004), an interagency program convened by CDOT to support environmental streamlining for the I-70 PEIS (Solomon 2007). As a part of the I-70 Eco-logical Project and in an effort to update the LIZs first mapped in 2004 with the most current wildlife data available, we developed a consistent and transparent process for identifying terrestrial connectivity zones within each bioregion along the I-70 Mountain Corridor. Recommendations for improving permeability for terrestrial wildlife will be focused in these revised LIZs (LIZ-2011), although additional measures may be warranted throughout the I-70 Mountain Corridor.

ANALYSIS METHODS

The analysis process for reassessing LIZs was comprised of three primary steps, detailed in the following sections:

1) For each bioregion within the study area (Table 1), identify at least one discrete priority zone based on identified primary criteria;
2) For each analysis segment, tally presence/absence of primary parameters;
3) Apply decision rules for delineating LIZs within each bioregion; apply secondary criteria as appropriate.

Table 1: Bioregions along the I-70 Mountain Corridor (CDOT 2004)

Bioregion	Mileposts
Western Slope Foothills	MP 130 – 170
Western Slope Montane	MP 170 – 182
Subalpine	MP 182 – 214 & MP 216 – 226
Alpine	MP 214 – 216
Eastern Slope Montane	MP 226 – 255

Wildlife habitat data were compiled for each target species within the I-70 Mountain Corridor for which spatial data were available. To determine which data layers to include in the analysis from all those present in the study area, we started with any threatened and endangered, sensitive, and other special status species found in the Corridor. From there, we added any other species presenting a safety, barrier, or habitat fragmentation concern in the context of the I-70 Mountain Corridor (see Table 2 for a list of all primary parameters). Appendix C details additional layers that are present in the study area but were not included in this analysis.

All primary parameters were ranked on a standardized scale so that all values at a given location could be summed (Table 2). Each parameter (i.e., target species or AVC data) was given a maximum score to avoid one parameter having an unreasonable weight within an analysis segment. This also helps 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. Canada lynx, Preble’s meadow jumping mouse and boreal toad were each allowed a maximum score of 20, the highest possible. Lynx and Preble’s are both listed as threatened under the Endangered Species Act, and boreal toad is a state endangered species and was on the candidate species list until the mid-2000s. River otter was given a maximum score of 12 because of their state threatened status.

For each focal species parameter, subparameters were identified, representing the different habitat values for that 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 subparameters (Appendix B).

In determining scores for each subparameter, habitat for 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. Modeled wildlife linkages (SREP 2008) were given the highest individual sub-parameter score because they indicate areas of the landscape that are specifically important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences).

Similarly, the modeled wildlife linkages (SREP 2008) were given the highest subparameter score for common species such as bighorn sheep and mule deer because these data layers relate directly to movement areas for these species. Sensitive habitat types were given an individual subparameter score based on the CDOW rankings (2008). Certain data layers, such as highway crossings, were included even though they were not ranked by CDOW because they were deemed important in the context of this study. These data layers were given a score based on scores for comparable data layers (Appendix B).

The most up-to-date AVC data available from Colorado State Patrol were used for all species except mountain lion, black bear and lynx. For these three species, a separate dataset maintained by CDOW was used as this dataset includes all collected roadkill incidents, not just those with a written accident report. Animal-vehicle collision data collected from both agencies were related to the nearest $1/10^{th}$ mile and summed to obtain the total number of AVCs per $1/10^{th}$ mile. Each AVC incident for all species except mountain lion, black bear and lynx were given a score of 1 with maximum score of 20 per $1/10^{th}$ mile segment. This ensured that nearly all (> 99%) possible AVC per $1/10^{th}$ mile values were captured, while preventing AVC values from exerting excessive influence in the identification of connectivity zones. Because black bear, mountain lion and Canada lynx are priority species for CDOW, a subparameter score of 6 was given to the first AVC per species in a given 1/10 mile segment. Each additional AVC for a given species in the same $1/10^{th}$ mile segment was given a score of 3 (applicable only to mountain lion in one $1/10^{th}$ mile segment). The AVCs per $1/10^{th}$ mile layer was then given a ½ mile buffer so that it could be overlaid with the wildlife habitat subparameters for analysis purposes.

Table 2: Primary criteria used to prioritize roadway segments. Highlighted rows indicate parameters, with subparameters listed beneath. Each parameter has a maximum possible score, such that the sum of multiple subparameters at a given location cannot have a value greater than the maximum score possible for that parameter.

PARAMETER			**MAXIMUM SCORE**
Subparameter	**Source**	**Decision Rule**	**Individual Score**
AVC			20
AVC	CSP (1993 to June 2006)	1-20 AVCs per tenth of a mile	1-20
BIGHORN SHEEP			10
Bighorn Sheep - LCL Modeled Wildlife Linkages	CNE 2008	Presence/absence	5
Bighorn Sheep – Migration Corridor*	CDOW 2010	Presence/absence	4
Bighorn Sheep – Production Areas*	CDOW 2010	Presence/absence	4
Bighorn Sheep – Severe Winter Range*	CDOW 2010	Presence/absence	4
Bighorn Sheep – Summer Concentration Area*	CDOW 2010	Presence/absence	3
Bighorn Sheep – Winter Concentration Area*	CDOW 2010	Presence/absence	4
Bighorn Sheep – Winter Range	CDOW 2010	Presence/absence	2
BLACK BEAR			10
Black Bear - AVC	CDOW (Sept 1994 to Jan 2010)	Presence/absence	6
Black Bear – Fall Concentration*	CDOW 2010	Presence/absence	3
Black Bear – Summer Concentration*	CDOW 2010	Presence/absence	2
BOREAL TOAD			20
Boreal Toad – Breeding Sites**	CDOW 2006	Presence/absence. Points buffered by 100m.	10
Boreal Toad – Observations**	CDOW 2006	Presence/absence. Points buffered by 100m.	6
Boreal Toad – Survey Sites**	CDOW 2006	Presence/absence. Points buffered by 100m.	6
ELK			10
Elk – Highway Crossings	CDOW 2010	Presence/absence	4
Elk - LCL Modeled	CNE, 2008	Presence/absence	5

Wildlife Linkages			
Elk – Migration Corridor*	CDOW 2010	Presence/absence	4
Elk – Production Area*	CDOW 2010	Presence/absence	4
Elk – Resident Population Area	CDOW 2010	Presence/absence	4
Elk – Severe Winter Range*	CDOW 2010	Presence/absence	3
Elk – Winter Concentration*	CDOW 2010	Presence/absence	3
Elk – Winter Range*	CDOW 2010	Presence/absence	2
LYNX			20
Lynx AVC	CDOW (July 1999 to July 2008)	Presence/absence	6
Lynx – Denning, Winter and/or Other Habitat**	USFS 2003	Presence/absence	6
Lynx - LCL Modeled Wildlife Linkages	CNE 2008	Presence/absence	10
Lynx – Potential Habitat**	CDOW 2006	Presence/absence	6
MOOSE			7
Moose – Concentration Area*	CDOW 2010	Presence/absence	4
Moose – Summer Range*	CDOW 2010	Presence/absence	1
Moose – Winter Range	CDOW 2010	Presence/absence	2
MOUNTAIN LION			9
Mountain Lion – AVC – 1st record	CDOW (Sept 1994 to Jan 2010)	Presence/absence	6
Mountain Lion – AVC – 2nd record	CDOW (Sept 1994 to Jan 2010)	Presence/absence	3
MULE DEER			10
Mule Deer – Concentration Area	CDOW 2010	Presence/absence	4
Mule Deer – Critical Winter Range*	CDOW 2010	Presence/absence	4
Mule Deer – Highway Crossings	CDOW 2010	Presence/absence	4
Mule Deer - LCL Modeled Wildlife Linkages	CNE 2008	Presence/absence	5
Mule Deer – Migration Corridor*	CDOW 2010	Presence/absence	4
Mule Deer – Resident	CDOW 2010	Presence/absence	4

Population Area			
Mule Deer – Severe Winter Range*	CDOW 2010	Presence/absence	3
Mule Deer – Winter Concentration Area*	CDOW 2010	Presence/absence	3
Mule Deer – Winter Range*	CDOW 2010	Presence/absence	2
NORTHERN LEOPARD FROG			4
Northern Leopard Frog – Potential Habitat	SWREGAP 2005	Presence/absence	4
PREBLE'S MEADOW JUMPING MOUSE			16
Preble's – Occupied Habitat**	FEMA/FWS 2010	Presence/absence	10
Preble's – Overall Range**	CDOW 2010	Presence/absence	6
RIVER OTTER			12
River Otter – Concentration Area*	CDOW 2010	Presence/absence	6
River Otter – Overall Range*	CDOW 2010	Presence/absence	6

**Priority wildlife habitat for economic species and species at risk (rare, threatened and endangered) for HB 1298 Species Impact Assessment as identified by CDOW, updated Jan. 29, 2008. Scores for this analysis correspond to CDOW's habitat ranking system (Appendix B): 'Very High' = 4; 'High' = 3; 'Moderate'=2 and 'Low' = 1*
***High priority wildlife habitat for other species at risk (rare, threatened and endangered)*

GIS Analysis Process
The first step in the GIS analysis process involved determining which wildlife habitat types, or subparameters, are present in the study area. To facilitate this process, a ½ mile buffer was mapped around a CDOT roads layer to define the study area around I-70. The ½ mile buffer was based on methodologies from the original LIZ identification process, which also used a ½ mile buffer to evaluate habitat data adjacent to the roadway. Using this buffered study area layer, a screen was run on several existing data layers to determine which wildlife habitat types of the identified parameters are present in the study area (Table 2).

For the next step, all of the subparameters present were clipped to the ½ mile buffered study area and assigned scores as detailed in Table 2. Each 1/10th mile segment in the buffered AVC layers were also given their appropriate score. All of the clipped and scored layers were merged into one data layer using the union tool in ArcGIS. A total score for each parameter was then calculated as the sum of the subparameters for each polygon in the study area (numerous polygons were created as a result of the summation process of all the data layers). All parameter totals were then checked and changed so that no parameter scored greater than its maximum possible score for a given polygon. A final score for each polygon was then determined by summing all of the scores across all parameters for that polygon.

The CDOT road layer was then split into 1 mile-long segments using mileposts as the dividing point. This process relied on the CDOT milepost layer, which was compiled for an invasive weeds mapping project based on the physical roadside milepost signs. However, the weeds-milepost layer does not include points for a stretch of roadway near Evergreen. Instead, for this section, we used a different CDOT milepost layer derived from a calculation of mileposts in a GIS using a linear referencing system. These are not the actual physical milepost locations, but, in most cases, they lie within close proximity to the physical milepost locations and provided a suitable surrogate where the weeds-mileposts data were not available. Once the roadway was divided into mile-long segments, these were further split into 1/10th mile segments using the divide tool in ArcGIS. This line layer was then buffered by a ½ mile to correspond to the defined study area. Due to complexities in the GIS calculations, only the eastbound alignment was used as the basis for buffering. Next, the acreage for each buffered 1/10th mile segment was calculated – referred to through the remainder of this report as a "slice". This slice layer was then unioned with the layer containing the merged subparameters and total scores.

The polygons within the new unioned layer were dissolved within a given 1/10th mile segment based on their total scores. To normalize the polygon scores and to prevent small polygons with a high total score from exerting excessive influence on the final rank of a slice, the acreage of these new polygons – defined by their common total scores – was calculated within each slice. The acreage of each polygon was then divided by the total acreage of the slice so that a percentage could be assigned to each polygon, representing the area of a slice occupied by that polygon. This percentage and the total score for each polygon were multiplied together. This layer was then dissolved into the 1/10th mile segments and the total scores of each individual polygon in a 1/10th mile segment were summed together to obtain a final score for each slice.

At this point, the dbf file for the summed slices layer was exported and opened in Excel. In Excel, the data were smoothed by summing a slice's total score with that of the two adjacent slices. This process acknowledges that one segment is likely influenced by its two neighboring segments (Huijser et al, 2008). The slices at each end of the analysis corridor are biased in this case because there is only one adjacent slice with which to smooth.

Based on these new, smoothed scores, the 0-20, 20-40, 40-60, 60-80 and 80-100 percentiles were calculated. The table was then imported back into the GIS, rejoined to its spatial layer, and exported as a new layer depicting the final analysis layer – total value per 1/10th mile slice.

Decision Rules for Defining Linkage Interference Zones Within Each Bioregion

Once the prioritization of 1/10th mile segments was completed, the next step was to create a set of decision rules to provide a consistent process for delineating individual LIZs within the highway corridor. The following suite of decision rules were applied to define LIZs:

- The minimum length for a LIZ is ½ mile (i.e., five 1/10th mile segments)
- Any Very High or High 1/10th mile road segments (i.e., 60-100th percentile) are automatically included in a LIZ.
- Up to ½ mile of continuous Medium-ranked road segments (40-60th percentile) are included in a LIZ if surrounded by Very High or High-ranked road segments.
- A 1/10th mile Low priority road segment (below the 40th percentile) is included in a LIZ only if surrounded by Very High or High road segments or within an included Medium-ranked segment.

- A Low priority road segment 2/10th mile long or greater marks the end of a LIZ.
- A LIZ may cross bioregion boundaries.

Secondary (refining) Criteria

LIZs were then further refined to exclude heavily developed areas along the highway corridor. Aerial imagery was used to conduct this refinement instead of the GIS land use/land cover layer, whose classification generalizes land use. In this manner, we were able to exclude major developed areas along the Corridor, while still including other residential areas where wildlife may still pass (e.g., low-medium density residential areas).

ANALYSIS RESULTS

Using this analysis procedure, 17 distinct connectivity zones were identified along the I-70 Mountain Corridor. These 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. Mileposts listed below indicate the starting point of a given 1/10th mile segment, such that, for example, MP 140 represents from 140 – 140.1. Each LIZ, and the parameters that define it, is further described in Table 3.

Western Slope Foothills Bioregion (MP 130 – 170)

LIZ-2011	Name	Mileposts Range
Zone A	Dotsero	130.9-131.3
Zone B	Wolcott West	151.2-154.1
Zone C	Wolcott	155.3-156.3
Zone D	Wolcott East	157.1- 159.6

Western Slope Montane Bioregion (MP 170 – 182)

Note: This bioregion includes the town of Vail, through which much of the roadway was ranked Very High and High priority. These areas were excluded from consideration as LIZs despite the high habitat values of the landscape because the extensive development in this area immediately adjacent to the roadway precludes effective implementation of highway mitigation measures.

LIZ-2011	Name	Mileposts Range
Zone E	Dowds Junction	169.4-172.8
Zone F	Vail (East)	176.8-180.1
Zone G	Gore Creek	180.9-182.1

Subalpine Bioregion (MP 182 – 214)

LIZ-2011	Name	Mileposts Range
Zone H	West Vail Pass	182.9 – 188.1
Zone I	East Vail Pass	191.8-194.2
Zone J	Wheeler Junction	195.2-195.8
Zone K	Laskey Gulch	207.3 – 209.0
Zone L	Hamilton Gulch	211.6-212.4

Alpine Bioregion (MP 214 – 216)
This bioregion has an existing land bridge over the interstate where the Eisenhower and Johnson Tunnels cross under the Continental Divide. No LIZs were identified in this bioregion.

Subalpine Bioregion (MP 216 – 226)

LIZ-2011	Name	Mileposts Range
Zone M	Bakerville	216.4 – 227.1

Eastern Slope Montane (MP 226 – 255)

LIZ-2011	Name	Mileposts Range
Zone N	Empire Junction	231.6 - 232.9
Zone O	Clear Creek Junction	243.0 – 244.9
Zone P	Beaver Brook	245.5-250.2
Zone Q	Mt. Vernon Creek	252.8 – 257.6

Table 3: Primary parameters driving how each LIZ-2011 was defined and mapped. Subparameters for each primary parameter that are present are listed below each parameter. Additional parameters that are present in the LIZ but had less influence on the total score are also listed.

LIZ-2011	MILE POSTS	PRIMARY PARAMETERS*	ADDITIONAL PARAMETERS
A – Dotsero	130.9-131.3	**Elk:** - LCL modeled wildlife linkage - Highway crossing - Severe winter range - Winter range **Mule deer:** - Critical winter range - Severe winter range - Winter concentration area - Winter range	AVCs, bighorn sheep, northern leopard frog, river otter
B – Wolcott West	151.2-154.1	**Animal-vehicle collisions** **Elk:** - LCL modeled wildlife linkage - Highway crossing - Winter concentration area - Winter range **Lynx:** - LCL modeled wildlife linkage - Potential habitat **Mule deer:** - Concentration area - Critical winter range - Highway crossing - Migration corridor - Severe winter range - Winter concentration area - Winter range	Northern leopard frog, river otter

C – Wolcott	155.3-156.3	**Elk:** - LCL modeled wildlife linkage - Highway crossing - Production area - Winter concentration area - Winter range **Mule deer:** - Critical winter range - Highway crossing - Migration corridor - Severe winter range - Winter concentration area - Winter range	AVCs, black bear, lynx, moose, mountain lion, northern leopard frog, river otter
D – Wolcott East	157.1-159.6	**Animal-vehicle collisions** **Elk:** - LCL modeled wildlife linkage - Highway crossing - Migration corridor - Severe winter range - Winter concentration area - Winter range **Mule deer:** - Critical winter range - Highway crossing - Migration corridor - Severe winter range - Winter concentration area - Winter range	Black bear, lynx, moose, northern leopard frog, river otter
E – Dowd Junction	169.4-172.8	**Elk:** - LCL modeled wildlife linkage - Production area - Severe winter range - Winter concentration area - Winter range **Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter, and/or other habitat	AVCs, black bear, moose, mule deer, northern leopard frog, river otter
F – Vail (East)	176.8-180.1	**Animal-vehicle collisions** **Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	Bighorn sheep, black bear, boreal toad, elk, moose, northern leopard frog, river otter
G – Gore Creek	180.9-182.1	**Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, black bear, elk, moose, northern leopard frog, river otter

H – West Vail Pass	182.9-188.1	**Lynx:** - AVC - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, elk, moose, northern leopard frog
I – East Vail Pass	191.8-194.2	**Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, elk, moose, northern leopard frog
J – Wheeler Junction	195.2-195.8	**Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, moose, northern leopard frog, river otter
K – Laskey Gulch	207.3-209	**Elk:** - Highway crossing - Migration corridor - Resident population area - Severe winter range - Winter range **Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, black bear, moose, mule deer, northern leopard frog, river otter
L – Hamilton Gulch	211.6-212.4	**Lynx:** - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, black bear, moose, northern leopard frog
M – Bakerville	216.4-227.1	**Lynx:** - AVC - LCL modeled wildlife linkage - Potential habitat - Denning, winter and/or other habitat	AVCs, bighorn sheep, black bear, boreal toad, elk, mountain lion, northern leopard frog
N – Empire Junction	231.6-232.9	**Lynx:** - LCL modeled wildlife linkage - Potential habitat	AVCs, bighorn sheep, black bear, elk, mule deer, northern leopard frog
O – Clear Creek Junction	243.0-244.9	**Elk:** - LCL modeled wildlife linkage - Winter range **Mule deer:** - LCL modeled wildlife linkage - Critical winter range - Highway crossing	AVCs, bighorn sheep, lynx, mountain lion, Preble’s meadow jumping mouse

		- Winter concentration area - Winter range	
P – Beaver Brook	245.5-250.2	**Animal-vehicle collisions** **Elk:** - LCL modeled wildlife linkage - Highway crossing - Resident population area - Winter concentration area - Winter range **Mule deer:** - LCL modeled wildlife linkage - Critical winter range - Highway crossing - Severe winter range - Winter range	Black bear, lynx, mountain lion, northern leopard frog, Preble's meadow jumping mouse
Q – Mt. Vernon Creek	252.8-257.6	**Animal-vehicle collisions** **Elk:** - Highway crossing - Resident population area - Winter concentration area - Winter range **Mule deer:** - Concentration area - Critical winter range - Highway crossing - Resident population area - Winter concentration area - Winter range	Black bear, lynx, mountain lion, Preble's meadow jumping mouse

* Primary parameters drive the identification of LIZs-2011. A parameter is considered to be a primary driver if the parameter scores half or more of the maximum score possible for that parameter across at least half of the area encompassed by that LIZ. CSP AVC data were a primary parameter when the total AVCs within the LIZ scored 20 or higher.

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 were identified in the 2011 analysis, compared to 13 in 2004. The 2004 analysis includes two LIZs for which sub-segments were also identified, specifically, LIZ 6 a & b (Upper and Lower West Vail Pass) and LIZ 9 a & b (Laskey Gulch and Hamilton to Dead Coon Gulch). While both analyses incorporated many of the same types of data layers, the LIZ-2004 process used a variety of techniques to delineate LIZs, including expert opinion, which was not used in the LIZ-2011 process. 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. Table 4 provides a side-by-side comparison of the LIZs identified in each analysis.

Table 4: Comparison of 2011 and 2004 LIZs. For each LIZ-2011, the approximately corresponding LIZ-2004 is listed. In some cases, there is a LIZ identified in one analysis that has not identified in others. In other cases, two LIZs-2011 may correspond to a single LIZ-2004, as, in general, longer segments were identified in the 2004 analysis.

LIZ-2011	Mileposts	LIZ-2004	Mileposts
Zone A (Dotsero)	130.9-131.3	LIZ 1 (Dotsero)	131.4-134.5
N/A		LIZ 2 (Eagle Airport to Town of Eagle)	142.0-145.3
Zone B (Wolcott West)	151.2-154.1	LIZ 3 (Eagle to Wolcott)	147.3-153.6
Zone C (Wolcott)	155.3-156.3	LIZ 4 (Wolcott to Avon)	154.4-166.5
Zone D (Wolcott East)	157.1- 159.6	LIZ 4 (Wolcott to Avon)	154.4-166.5
Zone E (Dowds Junction)	169.4-172.8	LIZ 5 (Dowd Canyon)	169.5-172.3
Zone F (Vail - East)	176.8-180.1	N/A	
Zone G (Gore Creek)	180.9-182.1	N/A	
Zone H (West Vail Pass)	182.9-188.1	LIZ 6a&b (West Vail Pass)	181.7-188.5
Zone I (East Vail Pass)	191.8-194.2	LIZ 7 (East Vail Pass to Copper)	190.4-194.0
Zone J (Wheeler Junction)	195.2-195.8	LIZ 8 (Officer's Gulch/Owl Canyon)	195.5-200.9
Zone K (Laskey Gulch)	207.3- 209	LIZ 9a (Laskey Gulch)	207.0-209.7
Zone L (Hamilton Gulch)	211.6-212.4	LIZ 9b (Hamilton Gulch to Dead Coon Gulch)	210.7-212.6
Zone M (Bakerville)	216.4-227.1	LIZ 10 (Herman Gulch to Bakerville)	216.7-220.8
Zone N (Empire Junction)	231.6-232.9	LIZ 11 (East of Empire on US 40)	I-70 Exit 232
N/A		LIZ 12 (Fall River)	237.2-238.2
Zone O (Clear Creek Junction)	243.0-244.9	N/A	
Zone P (Beaver Brook)	245.5-250.2	LIZ 13 (Mt Vernon Canyon)	246.5-258.1
Zone Q (Mt Vernon Creek)	252.8-257.6	LIZ 13 (Mt Vernon Canyon)	246.5-258.1

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Appendix A: GIS Data Definitions

Data	Source	Definition
Animal-vehicle collisions (AVC)	CSP (1993 to June 2006)	Animal-vehicle collision data reported to Colorado State Patrol from 1993 to June 2006. These data are maintained by Colorado Department of Transportation. Records for mountain lion and black bear were removed from this dataset to avoid duplication of the CDOW AVC data used for those species.
Bighorn Sheep – Migration Corridor	CDOW 2010	Migration corridor shows a specific, mappable site through which large numbers of animals migrate, and the loss of which would change migration routes.
Bighorn Sheep – Production Areas	CDOW 2010	Production area shows production (lambing) areas for bighorn sheep in Colorado. Production areas are defined as that part of the overall range occupied by pregnant females during a specific time period in the spring. This time period is May 1 to June 30 for Rocky Mtn bighorn sheep, and February 28 to May 1 for desert bighorn sheep. Only known production areas are mapped.
Bighorn Sheep – Severe Winter Range	CDOW 2010	Severe winter range shows the part of the winter range where 90% of the individual animals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. Not all populations exhibit migratory behavior during severe winters, many will stay within the defined winter range regardless of conditions. Thus, some populations may not have a mapped severe winter range distribution.
Bighorn Sheep – Summer Concentration Area	CDOW 2010	Summer concentration is defined as those areas where bighorn sheep concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance are generally characteristic of these areas to meet the high energy demands of lactation and lamb rearing.
Bighorn Sheep – Winter Concentration Area	CDOW 2010	Winter concentration shows the part of the winter range where animal densities are at least 200% greater than the surrounding winter range density during the same period used to define the winter range, in the average five winters out of ten.
Bighorn Sheep – Winter Range	CDOW 2010	Winter range shows the part of the overall range where 90% of the individuals are located during the average five winters out of ten, from the first heavy snowfall to spring green-up, or as a specific period which may defined for each unit.
Black Bear - AVC	CDOW (Sept 1994 to Jan 2010)	Animal-vehicle collision data for black bear collected by the Colorado Division of Wildlife from September 1994 to January 2010.
Black Bear – Fall Concentration	CDOW 2010	Fall concentration areas are defined as those parts of the overall range that are occupied from August 15 until September 30 for the purpose of ingesting large quantities of mast and berries to establish fat reserves for the winter hibernation period.
Black Bear – Summer Concentration	CDOW 2010	Summer concentration areas are defined as those parts of the overall range where activity is greater than the surrounding overall range during that period from June 15 to August 15.
Boreal Toad – Breeding Sites	CDOW 2006	Breeding sites are actual sites where breeding has occurred in recent history (since 1998).

Boreal Toad – Observations	CDOW 2006	Observations are reports sent into Tina Jackson at CDOW about boreal toad observations.
Boreal Toad – Survey Sites	CDOW 2006	Survey sites are locations where people have done surveys, either for boreal toads or habitat. The layer gives information about the site visited and whether or not toads were observed. It does not assess habitat quality. Only sites where toads were observed were included.
Elk – Highway Crossings	CDOW 2010	Highway crossing is defined as those areas where elk movements traditionally cross roads, presenting potential conflicts between elk and motorists.
Elk – Migration Corridor	CDOW 2010	Migration corridor is defined as a specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.
Elk – Production Area	CDOW 2010	Production area represents that part of the overall range of elk occupied by the females from May 15 to June 15 for calving. Only known areas are mapped and this does not include all production areas for the Data Analysis Unit.
Elk – Resident Population Area	CDOW 2010	Resident population Area is defined as an area used year-round by a population of elk. Individuals could be found in any part of the area at any time of the year; the area cannot be subdivided into seasonal ranges. It is most likely included within the overall range of the larger population.
Elk – Severe Winter Range	CDOW 2010	Severe winter range represents that part of the overall range of elk where 90% of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. The winter of 1983-1984 is a good example of a severe winter.
Elk – Winter Concentration	CDOW 2010	Winter concentration area represents that part of the winter range of elk where densities are at least 200% greater than the surrounding winter range density during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Data Analysis Unit.
Elk – Winter Range	CDOW 2010	Elk winter range is the part of the overall range of elk where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Data Analysis Unit.
LCL (Linking Colorado's Landscapes) Modeled Wildlife Linkages	SREP, 2008	LCL modeled wildlife linkages are areas of the landscape that are important for wildlife movement based on local and regional expertise and modeling of landscape characteristics (e.g. topography), wildlife habitat preferences and movement patterns.
Lynx - AVC	CDOW (July 1999 to July 2008)	Animal-vehicle collision data for lynx collected by the Colorado Division of Wildlife from July 1999 to July 2008.
Lynx – Denning, Winter and/or Other Habitat	USFS 2003	Lynx denning, winter and/or other habitat as mapped by USFS.
Lynx – Potential	CDOW 2006	Potential habitat is defined as those areas having the highest

Habitat		potential of lynx occurrences in the state. These areas usually contain positive, probable, or possible reports.
Moose – Concentration Area	CDOW 2010	Concentration area is defined as the part of the range of a species where densities are 200% higher than the surrounding area during a specific season.
Moose – Summer Range	CDOW 2010	Summer range is defined as that part of the overall range where 90% of the individuals are located during the summer months. This summer time frame will be delineated with specific start/end dates for each moose population within the state (i.e.: May 1 to Sept 15). Summer range is not necessarily exclusive of winter range.
Moose – Winter Range	CDOW 2010	Winter range shows that part of the overall range where 90% of the individuals are located during the winter months. This winter time frame will be delineated with specific start/end dates for each moose population within the state (i.e.: November 15 to April 1).
Mountain lion - AVC	CDOW (Sept 1994 to Jan 2010)	Animal-vehicle collision data for mountain lion collected by the Colorado Division of Wildlife from September 1994 to January 2010.
Mule Deer – Concentration Area	CDOW 2010	Concentration area shows that part of the overall range where higher quality habitat supports significantly higher densities than surrounding areas. These areas are typically occupied year round and are not necessarily associated with a specific season. Includes rough break country, riparian areas, small drainages, and large areas of irrigated cropland.
Mule Deer – Critical Winter Range	CDOW 2010	Critical winter range is a delineation of those parts of mule deer winter range that CDOW considers to be of highest priority for protection from disturbance from development. Protection of these parts of mule deer winter range is considered critical to sustain mule deer populations across Colorado. Mule deer critical winter range was created by combining subsets of mule deer winter concentration areas, high-density mule deer severe winter range, and Deer Data Analysis Units (DAUs). The high density severe winter range was created by calculating the 2006 post-hunt population estimate divided by the total winter range for each DAU. This was used to map to identify a "higher" and "lower" density threshold. A logical breakpoint was 7 deer per square km because a natural break occurred at this point and it was near the mean density. We then used this breakpoint in selecting those parts of the severe winter range where high deer densities increase the importance of the habitat.
Mule Deer – Highway Crossings	CDOW 2010	Highway crossing shows those areas where mule deer movements traditionally cross roads or railroads, presenting potential conflicts between mule deer and motorists/trains. (More than six highway mortalities per mile of highway or railroad per year is a guide that may be used to indicate highway crossings).
Mule Deer – Migration Corridor	CDOW 2010	Migration corridors shows a specific mappable site through which large numbers of animals migrate and loss of which would

		change migration routes.
Mule Deer – Resident Population Area	CDOW 2010	Resident population area shows an area that provides year-round range for a population of mule deer. The resident mule deer use all of the area all year; it cannot be subdivided into seasonal ranges although it may be included within the overall range of the larger population.
Mule Deer – Severe Winter Range	CDOW 2010	Severe winter range shows that part of the overall range where 90% of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.
Mule Deer – Winter Concentration Area	CDOW 2010	Winter concentration area shows the part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.
Mule Deer – Winter Range	CDOW 2010	Winter range shows that part of the overall range where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Date Analysis Unit.
Northern Leopard Frog – Potential Habitat	SWREGAP 2005	This data layer is a product of the Southwest Regional Gap Analysis Project. It depicts the predicted habitat for northern leopard frog. The following assumptions are associated with this GAP vertebrate habitat model[1]: 1. Species are assumed to occur within a polygon representing potential habitat but are not predicted to occur at any particular point within that polygon. 2. Species are assumed to be present within a polygon, but no assumptions are made about the abundance of the species in the polygon. 3. Species are assumed to be present in a polygon at least once in the last 10 years but need not be present every year in the last decade. 4. Species are assumed to be present during some portion of their life history, not necessarily during the entire year.
Preble's Meadow Jumping Mouse – Occupied Habitat	FEMA/FWS 2010	This layer depicts the 100-year floodplain of Beaver Brook with a 300 foot buffer. FWS verified that Preble's meadow jumping mouse has been trapped in this area, and it is considered occupied habitat. A 300 foot buffer was applied to the 100-year floodplain to be consistent with how FWS determines impacts for section 7 consultation (Alison Michael, FWS, pers. comm.). The 100-year floodplain was determined by using the Flood Zone X (FEMA, pers. comm.) attribute from the FEMA GIS data layer titled *S_Fld_Haz_Ar* which depicts the location and attributes flood insurance risk zones on the DFIRM.
Preble's Meadow Jumping Mouse – Overall Range	CDOW 2007	Overall range is defined as the area which encompasses the probable range of Preble's meadow jumping mouse along the Front Range of Colorado below 7600' elevation eastward to include those hydrounits identified by the Preble's Technical Working Group. Preble's meadow jumping mouse is primarily

[1] Csuti, B. and P. Crist. 1998. Methods for Assessing Accuracy of Animal Distribution Maps, Gap Analysis Program, University of Idaho, Moscow, Idaho. http://www.gap.uidaho.edu/

		associated with riparian corridors of small intermittent and perennial streams where riparian herbaceous and riparian shrub (primarily willow) dominate.
River Otter – Concentration Area	CDOW 2010	Concentration areas are defined as areas where river otters are known to concentrate; otter sightings and signs of otter activity are more frequent in these areas than in their overall range.
River Otter – Overall Range	CDOW 2010	Overall range is defined as those areas encompassing all mapped seasonal activity areas within the observed range of a population of river otters.
Data	**Source**	**Definition**
Animal-vehicle collisions (AVC)	CSP (1993 to June 2006)	Animal-vehicle collision data reported to Colorado State Patrol from 1993 to June 2006. These data are maintained by Colorado Department of Transportation. Records for mountain lion and black bear were removed from this dataset to avoid duplication of the CDOW AVC data used for those species.
Bighorn Sheep – Migration Corridor	CDOW 2010	Bighorn Migration Corridors shows a specific, mappable site through which large numbers of animals migrate, and the loss of which would change migration routes.
Bighorn Sheep – Production Areas	CDOW 2010	Bighorn Production Area shows production (lambing) areas for bighorn sheep in Colorado. Production areas are defined as that part of the overall range occupied by pregnant females during a specific time period in the spring. This time period is May 1 to June 30 for Rocky Mtn bighorn sheep, and February 28 to May 1 for desert bighorn sheep. Only known production areas are mapped.
Bighorn Sheep – Severe Winter Range	CDOW 2010	Bighorn Severe Winter shows the part of the winter range where 90% of the individual animals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. Not all populations exhibit migratory behavior during severe winters, many will stay within the defined winter range regardless of conditions. Thus, some populations may not have a mapped severe winter range distribution.
Bighorn Sheep – Summer Concentration Area	CDOW 2010	Bighorn Summer Concentration is defined as those areas where bighorn sheep concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance are generally characteristic of these areas to meet the high energy demands of lactation and lamb rearing.
Bighorn Sheep – Winter Concentration Area	CDOW 2010	Bighorn Winter Concentration shows the part of the winter range where animal densities are at least 200% greater than the surrounding winter range density during the same period used to define the winter range, in the average five winters out of ten.
Bighorn Sheep – Winter Range	CDOW 2010	Bighorn Winter Range shows the part of the overall range where 90% of the individuals are located during the average five winters out of ten, from the first heavy snowfall to spring green-up, or as a specific period which may defined for each unit.
Black Bear - AVC	CDOW (Sept 1994 to Jan 2010)	Animal-vehicle collision data for black bear collected by the Colorado Division of Wildlife from September 1994 to January 2010.
Black Bear – Fall	CDOW 2010	Fall Concentration Areas are defined as those parts of the overall

Concentration		range that are occupied from August 15 until September 30 for the purpose of ingesting large quantities of mast and berries to establish fat reserves for the winter hibernation period.
Black Bear – Summer Concentration	CDOW 2010	Summer Concentration Areas are defined as those parts of the overall range where activity is greater than the surrounding overall range during that period from June 15 to August 15.
Boreal Toad – Breeding Sites	CDOW 2006	Breeding Sites are actual sites where breeding has occurred in recent history (since 1998).
Boreal Toad – Observations	CDOW 2006	Observations are reports sent into Tina Jackson at CDOW about boreal toad observations.
Boreal Toad – Survey Sites	CDOW 2006	Survey Sites are locations where people have done surveys, either for boreal toads or habitat. The layer gives information about the site visited and whether or not toads were observed. It does not assess habitat quality. Only sites where toads were observed were included.
Elk – Highway Crossings	CDOW 2010	Highway Crossing is defined as those areas where elk movements traditionally cross roads, presenting potential conflicts between elk and motorists.
Elk – Migration Corridor	CDOW 2010	Migration Corridors is defined as a specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.
Elk – Production Area	CDOW 2010	Elk Production Area represents that part of the overall range of elk occupied by the females from May 15 to June 15 for calving. Only known areas are mapped and this does not include all production areas for the Data Analysis Unit.
Elk – Resident Population Area	CDOW 2010	Elk Resident Population Area is defined as an area used year-round by a population of elk. Individuals could be found in any part of the area at any time of the year; the area cannot be subdivided into seasonal ranges. It is most likely included within the overall range of the larger population.
Elk – Severe Winter Range	CDOW 2010	Elk Severe Winter Range represents that part of the overall range of elk where 90% of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten. The winter of 1983-1984 is a good example of a severe winter.
Elk – Winter Concentration	CDOW 2010	Elk Winter Concentration Area represents that part of the winter range of elk where densities are at least 200% greater than the surrounding winter range density during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Data Analysis Unit.
Elk – Winter Range	CDOW 2010	Elk Winter Range is the part of the overall range of elk where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Data Analysis Unit.
LCL (Linking Colorado's Landscapes) Modeled Wildlife	CNE, 2008	Modeled areas of the landscape that are important for wildlife movement based on local and regional expertise and modeling of landscape characteristics (e.g. topography), wildlife habitat preferences and movement patterns.

Linkages		
Lynx - AVC	CDOW (July 1999 to July 2008)	Animal-vehicle collision data for lynx collected by the Colorado Division of Wildlife from July 1999 to July 2008.
Lynx – Denning, Winter and/or Other Habitat	USFS 2003	Lynx Denning, Winter and/or Other habitat as mapped by USFS.
Lynx – Potential Habitat	CDOW 2006	Potential Habitat is defined as those areas having the highest potential of lynx occurrences in the state. These areas usually contain positive, probable, or possible reports.
Moose – Concentration Area	CDOW 2010	Moose Concentration Area is defined as the part of the range of a species where densities are 200% higher than the surrounding area during a specific season.
Moose – Summer Range	CDOW 2010	Moose Summer Range is defined as that part of the overall range where 90% of the individuals are located during the summer months. This summer time frame will be delineated with specific start/end dates for each moose population within the state (i.e.: May 1 to Sept 15). Summer range is not necessarily exclusive of winter range.
Moose – Winter Range	CDOW 2010	Moose Winter Range shows that part of the overall range where 90% of the individuals are located during the winter months. This winter time frame will be delineated with specific start/end dates for each moose population within the state (i.e.: November 15 to April 1).
Mountain lion - AVC	CDOW (Sept 1994 to Jan 2010)	Animal-vehicle collision data for mountain lion collected by the Colorado Division of Wildlife from September 1994 to January 2010.
Mule Deer – Concentration Area	CDOW 2010	Mule Deer Concentration Area shows that part of the overall range where higher quality habitat supports significantly higher densities than surrounding areas. These areas are typically occupied year round and are not necessarily associated with a specific season. Includes rough break country, riparian areas, small drainages, and large areas of irrigated cropland.
Mule Deer – Critical Winter Range	CDOW 2010	Mule Deer Critical Winter Range is a delineation of those parts of Mule Deer Winter Range that CDOW considers to be of highest priority for protection from disturbance from development. Protection of these parts of Mule Deer Winter Range is considered critical to sustain mule deer populations across Colorado. Mule Deer Critical Winter Range was created by combining subsets of Mule Deer Winter Concentration Areas, high-density Mule Deer Severe Winter Range, and Deer Data Analysis Units (DAUs). The high density severe winter range was created by calculating the 2006 post-hunt population estimate divided by the total winter range for each DAU. This was used to map to identify a "higher" and "lower" density threshold. A logical breakpoint was 7 deer per square km because a natural break occurred at this point and

		it was near the mean density. We then used this breakpoint in selecting those parts of the severe winter range where high deer densities increase the importance of the habitat.
Mule Deer – Highway Crossings	CDOW 2010	Mule Deer Highway Crossing shows those areas where mule deer movements traditionally cross roads or railroads, presenting potential conflicts between mule deer and motorists/trains. (More than six highway mortalities per mile of highway or railroad per year is a guide that may be used to indicate highway crossings).
Mule Deer – Migration Corridor	CDOW 2010	Mule Deer Migration Corridors shows a specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.
Mule Deer – Resident Population Area	CDOW 2010	Mule Deer Resident Population Area shows an area that provides year-round range for a population of mule deer. The resident mule deer use all of the area all year; it cannot be subdivided into seasonal ranges although it may be included within the overall range of the larger population.
Mule Deer – Severe Winter Range	CDOW 2010	Mule Deer Severe Winter Range shows that part of the overall range where 90% of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.
Mule Deer – Winter Concentration Area	CDOW 2010	Mule Deer Winter Concentration Area shows the part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.
Mule Deer – Winter Range	CDOW 2010	Mule Deer Winter Range shows that part of the overall range where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each Date Analysis Unit.
Northern Leopard Frog – Potential Habitat	SWREGAP 2005	This data layer is a product of the Southwest Regional Gap Analysis Project. It depicts the predicted habitat for Northern Leopard Frog. The following assumptions are associated with this GAP vertebrate habitat model[2]: 1. Species are assumed to occur within a polygon representing potential habitat but are not predicted to occur at any particular point within that polygon. 2. Species are assumed to be present within a polygon, but no assumptions are made about the abundance of the species in the polygon. 3. Species are assumed to be present in a polygon at least once in the last 10 years but need not be present every year in the last decade. 4. Species are assumed to be present during some portion of their life history, not necessarily during the entire year.
Preble's Meadow Jumping Mouse – Occupied Habitat	FEMA/FWS 2010	This layer depicts the 100-year floodplain of Beaver Brook with a 300 foot buffer. FWS verified that Preble's Meadow Jumping Mouse has been trapped in this area, and it is considered occupied habitat. A 300 foot buffer was applied to the 100-year floodplain to be consistent with how FWS determines impacts for

[2] Csuti, B. and P. Crist. 1998. Methods for Assessing Accuracy of Animal Distribution Maps, Gap Analysis Program, University of Idaho, Moscow, Idaho. http://www.gap.uidaho.edu/

		section 7 consultation (Alison Michael, FWS, pers. comm.). The 100-year floodplain was determined by using the Flood Zone X (FEMA, pers. comm.) attribute from the FEMA GIS data layer titled *S_Fld_Haz_Ar* which depicts the location and attributes flood insurance risk zones on the DFIRM.
Preble's Meadow Jumping Mouse – Overall Range	CDOW 2007	Overall Range is defined as the area which encompasses the probable range of Preble's Meadow Jumping Mouse along the Front Range of Colorado below 7600' elevation eastward to include those hydrounits identified by the Preble's Technical Working Group. Preble's Meadow Jumping Mouse is primarily associated with riparian corridors of small intermittent and perennial streams where riparian herbaceous and riparian shrub (primarily willow) dominate.
River Otter – Concentration Area	CDOW 2010	Concentration Areas are defined as areas where river otters are known to concentrate; otter sightings and signs of otter activity are more frequent in these areas than in their overall range.
River Otter – Overall Range	CDOW 2010	Overall Range is defined as those areas encompassing all mapped seasonal activity areas within the observed range of a population of river otters.

Appendix B: GIS Data Score Justification

Data	Score	Justification of Score
AVC	1-20	The actual AVC number was used up to a maximum of 20. This ensured coverage of a substantial proportion (> 99%) of possible AVC values while preventing AVC values from exerting excessive influence in the identification of connectivity zones. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Bighorn - LCL Modeled Wildlife Linkages	5	Modeled wildlife linkages for bighorn sheep were given the highest individual sub-parameter score because they indicate areas of the landscape that are important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Bighorn Sheep – Migration Corridor	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Bighorn Sheep – Production Areas	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Bighorn Sheep –Severe Winter Range	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Bighorn Sheep – Summer Concentration Area	3	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Bighorn Sheep – Winter Concentration Area	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Bighorn Sheep – Winter Range	2	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was identified as key wildlife habitat by CDOW and CDOT (2004). The score given to this layer for this analysis corresponds to that given to elk and mule deer winter range which is 2.

Black Bear – AVC	6	Because black bear is are priority species for CDOW, a sub-parameter score of 6 was given to the first AVC per species in a given 1/10 mile segment. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Black Bear – Fall Concentration	3	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Black Bear – Summer Concentration	2	This layer was ranked as a 'Moderate' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 2.
Boreal Toad – Breeding Sites	10	Boreal toad breeding sites were given the highest individual sub-parameter score for boreal toads because they indicate the most sensitive areas for this species. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Boreal Toad – Observations	6	Boreal toad observations were treated like suitable habitat for the species and given a score of 6, the same score given to the lynx potential habitat layer (which was ranked in House Bill 1298). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Boreal Toad – Survey Sites	6	Boreal toad survey sites were treated like suitable habitat for the species and given a score of 6, the same score given to the lynx potential habitat layer (which was ranked in House Bill 1298). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Elk – Highway Crossings	4	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis is 4 which corresponds to that given to other "Very High" priority layers.
Elk - LCL Modeled Wildlife Linkages	5	Modeled wildlife linkages for elk were given the highest individual sub-parameter score because they indicate areas of the landscape that are important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Elk – Migration Corridor	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The

		corresponding score for this analysis is 4.
Elk – Production Area	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Elk – Resident Population Area	4	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis is 4 which corresponds to that given to other "Very High" priority layers.
Elk – Severe Winter Range	3	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Elk – Winter Concentration	3	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Elk – Winter Range	2	This layer was ranked as a 'Moderate' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 2.
Lynx – AVC	6	Because Canada lynx are priority species for CDOW, a sub-parameter score of 6 was given to the first AVC per species in a given 1/10 mile segment. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Lynx – Denning, Winter and/or Other Habitat	6	Lynx denning, winter and/or other habitat was considered similar to the lynx potential habitat layer. Therefore, it was given the same score for this analysis as the potential habitat layer (see below). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Lynx - LCL Modeled Wildlife Linkages	10	Modeled wildlife linkages for lynx were given the highest individual sub-parameter score because they indicate areas of the landscape that are important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences). Because lynx are an ESA threatened species, this layer was given a score double of that of more common species. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Lynx – Potential Habitat	6	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for

		priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 6 (the common species score doubled because lynx are an ESA threatened species).
Moose – Concentration Area	4	This layer was ranked as a 'Moderate' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). Normally, that should mean the corresponding score for this analysis is 2. However, in the context of this study, it was deemed that this layer should get more weight and was, therefore, given a score of 4, like that of the concentration area layer for mule deer.
Moose – Summer Range	1	This layer was ranked as a 'Low' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 1.
Moose – Winter Range	2	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis corresponds to that given to elk and mule deer winter range which is 2.
Mountain lion - AVC	6/3	Because mountain lion is priority species for CDOW, a sub-parameter score of 6 was given to the first AVC per species in a given 1/10 mile segment. Each additional AVC for a given species in the same 1/10 mile segment was given a score of 3. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Mule Deer – Concentration Area	4	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis is 4 which corresponds to that given to other "Very High" priority layers.
Mule Deer – Critical Winter Range	4	This layer was ranked as a 'Very High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Mule Deer – Highway Crossings	4	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis is 4 which corresponds to that given to other "Very High" priority layers.
Mule Deer - LCL Modeled	5	Modeled wildlife linkages (CNE 2008) for mule deer

Wildlife Linkages		were given the highest individual sub-parameter score because they indicate areas of the landscape that are important for wildlife movement and incorporate a variety of information (e.g. local and regional expertise, landscape characteristics, wildlife habitat preferences). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Mule Deer – Migration Corridor	4	This layer was ranked as a ‘Very High’ priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 4.
Mule Deer – Resident Population Area	4	This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008). However, this layer was included in this analysis because it was deemed important to the context of this study. The score given to this layer for this analysis is 4 which corresponds to that given to other “Very High” priority layers.
Mule Deer – Severe Winter Range	3	This layer was ranked as a ‘High’ priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Mule Deer – Winter Concentration Area	3	This layer was ranked as ‘High’ in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 3.
Mule Deer – Winter Range	2	This layer was ranked as a ‘Moderate’ priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 2.
Northern Leopard Frog – Potential Habitat	4	Northern leopard frog potential habitat was included because this species is a UFSF Sensitive Species. Because this is a modeled habitat layer and a sensitive species, it received a score double that of the more general habitat layer for common species (i.e. mule deer winter range). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Preble’s Meadow Jumping Mouse – Occupied Habitat	10	Preble’s meadow jumping mouse occupied habitat was given the highest individual sub-parameter score for Preble’s because it indicates the most sensitive areas for this species. This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).
Preble’s Meadow Jumping Mouse – Overall Range	6	Preble’s meadow jumping mouse overall range was given a score of 6, the same score given to the lynx potential habitat layer (which was ranked in House Bill 1298). This layer was not ranked in House Bill 1298 Species Impact Assessment (CDOW 2008).

River Otter – Concentration Area	6	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 6 (the common species score doubled because river otters are a state threatened species).
River Otter – Overall Range	6	This layer was ranked as a 'High' priority in House Bill 1298 Species Impact Assessment (CDOW 2008) for priority wildlife habitat for economic species and species at risk (rare, threatened and endangered). The corresponding score for this analysis is 6 (the common species score doubled because river otters are a state threatened species).

Appendix C: GIS Data Excluded from Ranking Process

These data are found in the study area but were excluded from the analysis for the reasons listed in the table.

Data	Reason for Exclusion
Element Occurrence Records - Colorado Natural Heritage Program	Data are points and there is no consistent way to include them in the ranking process (i.e. what buffer should be used, etc.).
Land type data (i.e. State Wildlife Areas, Roadless Areas, CNHP Potential Conservation Areas)	Data layers are not wildlife movement related.
SWREGAP data	The only species for which these data are included is northern leopard frog because no other data are available for this species. For all other species, either other data are available, or the species is not on the list of focal species.
Bird data	The only bird species considered for inclusion in this analysis is greater sage-grouse because they move on the ground as well as fly. However, only historic data intersects with the study area, so this species was also not included. Otherwise, avian species are an acknowledged gap in this project.
Fish data	Fish data will be included in our aquatic connectivity section. Therefore, no fish species are included in this analysis to refine the LIZs because they are a terrestrial designation.
Mountain lion – CDOW mapped overall range, peripheral range and human conflict areas	Overall range was not included because it is too general. Peripheral range and human conflict areas were not included because the data definitions do not fit into the scope of this project.
Preble’s meadow jumping mouse – trapping points	The author of this data is unknown. Tina Jackson at CDOW does not think PMJM’s are an issue in our study area. Alison Michael at USFWS is aware that PMJM have been successfully trapped near Beaver Brook so a data layer was included for that area.
Boreal toad – current range	This data layer is based on watersheds and is too general. Tina Jackson at CDOW thought that the breeding sites should be sufficient for this species. Survey sites and observation points are also being included.
Canada lynx – BLM/FS lynx linkages and BLM/FS mapped LAUs	The lynx linkage data are not included because the LCL habitat linkages are already included in the analysis. The BLM/FS lynx linkages were used to create the LCL data. LAUs are not included because mapped denning, winter and other habitat is being used instead. These layers are more specific than the LAU layer.
Migration patterns for mule deer, bighorn and elk	These data layers are lines, not polygons, and the LCL linkage and CDOW migration corridor data are already included.
Abert’s squirrel – overall range	This data layer is too general, and “while the highway does present a barrier to the squirrel, it isn’t a special concern from a connectivity or habitat fragmentation point-of-view due to the amount of available habitat, the large populations on both sides of the highway and their behavior patterns” (Jeff

	Peterson, CDOT, personal communication).
Bighorn sheep – overall and summer range	Not included because too general and including several other sensitive habitat types for this species.
Black bear – overall range and human conflict area	Overall range is not included because it is too general. Human conflict area is not included because the data definitions do not fit into the scope of this project.
Elk – overall range, summer concentration and summer range	Not included because too general and including several other sensitive habitat types for this species.
Moose – overall range	Not included because too general
Mountain goat – migration corridor, overall and summer range	Not including because not a focal species that presents a connectivity issue and there are areas where connectivity is NOT desired for this species (CDOT 2004).
Mule deer – overall and summer range	Not included because too general and including several other sensitive habitat types for this species.
White-tail prairie dog	Not including because the only data layer to intersect is internal CNE data of which the original author is unknown. No CDOW data either intersects or is to the north and south (inferring a potential connectivity issue) of the study area.
Black-tail prairie dog – overall range	Not including because too general and only at the very eastern edge of the study area.

APPENDIX E

Recommendations for Enhancing Connectivity for Terrestrial and Aquatic Wildlife along the I-70 Mountain Corridor

CONTENTS

Note: Maps of each of the LIZs-2011 and watersheds of the I-70 Mountain Corridor displaying the locations of connectivity recommendations are available by accessing the *I-70 Connectivity Recommendations* document on the I-70 Mountain Corridor CSS website. Go to the 'Must See, Must Do' sidebar at: http://i70mtncorridorcss.com/corevalues/healthy-environment/wildlife

LIZ A: Dotsero

Mileposts: 130.9 – 131.3 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 0.5 miles

Target Species	*Species Movement Guilds*
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

*Secondary Target Species**

Mountain Lion	Northern Leopard Frog

* Bighorn sheep removed as secondary target species because habitat is primarily north of interstate and domestic sheep are present south of the interstate. River otter occurs in the area, however as there are no aquatic crossings in this LIZ, otter movement is not a concern in the LIZ so long as they can move up and down the Colorado River corridor, which runs parallel to the interstate.

Animal-Vehicle Collisions: Moderate to Low

Status of Adjacent Lands: Public (BLM) lands and some private lands north of I-70; Land trust property along riparian corridor south of I-70.

Site Discussion: Level/Riparian. No structures inventoried. Game fencing on both sides of interstate throughout LIZ. I-70 parallels the north side of the Colorado River through this LIZ.

Connectivity Recommendations
Install a bridge underpass suitable for deer and elk passage and include features to accommodate amphibian and small mammal passage. Tie structure into existing wildlife fencing. When reconstructing interstate, install additional pipe culverts to accommodate passage for small and medium-sized mammals and amphibians. Because the road level is low relative to the river, which runs parallel, this recommendation requires raising the road bed to install a sufficiently-sized underpass or construct an overpass. Coordinate with BLM and land trust.

LIZ B: Wolcott West

Mileposts: 151.2 – 154.1 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 3.0 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Mountain Lion	Northern Leopard Frog
River Otter	

Animal-Vehicle Collisions: Ranges from Very High to Low

Status of Adjacent Lands: Mostly public (BLM), but eastern portion of LIZ is private (east of approximately MP 152.5).

Site Discussion: Level/Riparian - Moderately broad drainage. Steep slopes to north and south. Game fencing on both sides of interstate throughout LIZ.

Connectivity Recommendations
Tie new and existing structures into existing wildlife fencing and ensure fencing connects structures through median between EB and WB lanes. Where concrete median barriers are present, add median gaps to accommodate small mammals every quarter mile.

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
n/a	151.2 - 152.5	No suitable crossing structures in this segment	Install at least one large bridge underpass suitable for lynx, deer and elk passage; include features to accommodate amphibian passage.	No
JP126†	152.6	Pipe. Wildlife fencing blocks structure entrances on both N & S sides.	Maintain pipe for small and medium-sized mammal passage. Replace concrete headwall at north entrance with soil and vegetation. Move wildlife fencing run over the top of the pipe rather than running in front of structure entrances. Add small mammal fencing to connect structures under EB and WB lanes through open median. Remove accumulated sediment limiting through-passage.	Yes
JP119	153.0	Divided bridge over private access road, tied into existing wildlife fencing along I -70.	Replace concrete bridge abutments with natural slopes; Replace existing cattle fencing with wildlife-friendly fencing. Revegetate approaches where feasible.	Yes
JP118	153.3	Long, narrow Concrete Box Culvert (8x8x225') with median skylight. Pipe culvert under frontage road at south entrance.	Culvert cannot be made functional for elk, but could be enhanced for deer and lynx; also too long for deer population-level movements. Widen culvert. Add features to prevent road debris/trash from entering through the median skylight (Note: the benefits of culvert skylights remain unconfirmed, although daylighting, in concept, is desirable). Add natural substrate and baffles to create a natural floor surface. Elk passage at this location require replacing culvert with a bridge structure.	No
JP116†	154.0	Divide bridge over Eagle River, 2-lane paved road (Hwy 6) and RR (not in use). Structure connects into wildlife fencing in both directions.	Maintain natural banks and vegetation cover on west side of river. Minimize human activity on north side of Eagle River to encourage wildlife use. Widen and improve dry pathway between river and Hwy 6 on east side of structure by moving guardrail closer to road and maintaining a dirt/gravel pathway through large boulders lining the river bank. Replace or cover gabian wall abutment with natural substrate.	Yes

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ C: Wolcott

Mileposts: 155.3 – 156.3 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 1 mile

Target Species	*Species Movement Guilds*
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Black Bear	Canada Lynx
Moose	Mountain Lion
Northern Leopard Frog	River Otter

Animal-Vehicle Collisions: Ranges from High to Very High

Status of Adjacent Lands: Mostly private with some BLM lands around MP 155.9-156

Site Discussion: Topography adjacent to interstate is fairly level. No existing structures present in LIZ. Game fencing on both sides of interstate throughout LIZ.

Connectivity Recommendations
Install bridge underpass suitable for deer and elk passage, including features to accommodate amphibian and small mammal passage. Tie structure into existing wildlife fencing. When reconstructing interstate, install additional pipe culverts to accommodate passage for small and medium-sized mammals and amphibians.

LIZ D: Wolcott East

Mileposts: 157.1 – 159.6 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 2.6 miles

Target Species	*Species Movement Guilds*
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Black Bear	Canada Lynx
Moose	Mountain Lion
Northern Leopard Frog	River Otter

Animal-Vehicle Collisions: Ranges from High to Very High

Status of Adjacent Lands: Mostly private

Site Discussion: Surrounding topography is level/sloped. Game fencing on both sides of interstate throughout LIZ.

Connectivity Recommendations
Recommend a combination of new wildlife crossing structures and improvements to existing infrastructure. When reconstructing interstate, install additional pipe culverts to accommodate passage for amphibians and small and medium-sized mammals.

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
n/a	157.1-158.0	Segment has no existing structures suitable for passage by primary target species. The meadow area north of the I-70 in this area is currently under review for development of major community center; proposal to move Hwy 6 closer to I-70, increasing the roadway barrier.	Install a bridge underpass suitable for deer and elk passage (replace CBC at MP 157.2 or install a new structure elsewhere). Include features to accommodate amphibian and small mammal passage. Tie structure into existing wildlife fencing. Coordinate with community to pursue a combination of land protection and cluster development away from a proposed wildlife crossing.	No
JP117	157.2	CBC with two paved drainage pipes feeding in from south side. Gated on north side. Trash/debris in culvert. Skylight in median. Adjacent escape ramp	Requires careful coordination with landowner(s) - may need to control livestock whil allowing wildlife passage.	No
JP115	157.6	Pipe culvert	Structure is not suitable for improvements to accommodate target species. Maintain for small animal movement, and possibly install small mammal shelf through culvert.	No
JP114	158.7	Large divided bridge spanning Hwy 6, Eagle River and RR. Bridge spans natural riverbanks on both sides of the river.	Replace concrete abutments with natural slopes. Connect existing wildlife fencing completely to structure so that there are no gaps. Maintain natural vegetation and riverbanks through structure. Traffic on Hwy 6 may preclude some wildlife movement, but large span offers large area for wildlife to traverse. Minimize human access on non-roaded side of river to encourage wildlife passage.	Yes
JP112	159.4	Concrete box culvert with paved road through it.	Structure is not suitable for improvements to accommodate target species. Integrate terrestrial and aquatic connectivity needs at this location by replacing the box culvert and pipe (aquatic site JP113) with a bridge spanning both the road and stream. Restore the riparian channel and construct year-round dry pathways through structure.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ E: Dowds Junction

Mileposts: 169.4 – 172.8 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 3.5 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Black Bear	Canada Lynx
Moose	Mountain Lion
Northern Leopard Frog	River Otter

Animal-Vehicle Collisions: Range from Moderate to High

Status of Adjacent Lands: USFS, State Land Board, and CDOW with some private and city land at the east end of LIZ

Site Discussion: Steep slopes through eastern portion of LIZ. Gore Creek, which feeds into the Eagle River at the western end of the LIZ, runs parallel to the interstate through this segment. Game fencing on both sides of interstate through eastern half of the zone.

Connectivity Recommendations
The recommendations provided below relate to the current roadway alignment. Alternatively, if the interstate is tunneled around this location (from approximately MP 169.8 – 172.3), then recommend restoring native habitat through the LIZ and coordinate with the Forest Service to manage the as a wildlife corridor (and manage human activities accordingly).

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP048†	170	Concrete box culvert with motorized access to Whiskey Creek Trailhead on south side of I-70. Highway 6 passes immediately in front of north entrance.	Preferred Recommendation: Replace structure with large bridge underpass that would allow animals to cross safely under I-70 and Hwy 6. Create a new parking area away from the bridge to allow people to access the Whiskey Creek Trailhead. Restore habitat under bridge and at both approaches, leading all the way down to the Eagle River on the north side.	No

JP048†	170	Same as above.	Minimum Recommendation: Remove & restore dirt parking area in front of south entrance and prevent cars/trucks from driving through the structure. Divert trail users to park on the north end of the structure. Add sediment baffles and maintain sediment pathway through the structure. Restore vegetation around south side entrance and add wildlife crossing warning signs and rumble strips to Hwy 6 at the north entrance. Animals are naturally funneled below the hwy level at this location; fencing may not be necessary, although this question requires further investigation. In lieu of fencing, consider adding a concrete shoulder barrier to the north side of the highway, extending beyond where the drainage reaches the same level as the roadway.	Yes
n/a	170.5	Narrow drainage bisected by I-70	Add 10x10' box culvert for carnivores (2004 LIZ recommendation)	No
JP047†	171.1	Large bridge spanning 2-lane road, Eagle River and RR (no longer in use). Tied into wildlife fencing on east side; Hwy exit ramps immediately to west of structure. Traffic on Hwy 6 precludes some wildlife movement, but large span offers large area for wildlife to traverse on east side of river. Mule deer use of this structure has increased since the trains have stopped running. Frequent human activity also occurs on this side of the river.	Construct dry, flat pathways (>3' wide) through the riprap slopes on both sides of the river and connecting to the adjacent habitat. Restore natural stream banks through the structure and leading under the adjacent bridge to north.	Yes
JP046	171.3	Bridge over Gore Creek and bike path. Structure tied into existing wildlife fencing	Preferred Recommendation: Widen structure to restore natural stream banks through the structure.	No

JP046	171.3	Same as above	Minimum Recommendation: Construct dry, flat pathways (≥3' wide) through the riprap abutments on both sides of the river connecting to adjacent habitat.	Yes
JP045†	171.8	Concrete box culvert with median skylight; bikepath crosses overhead at south side entrance. Tied into wildlife fencing. Sediment baffles create a dirt pathway through the length of the structure. Structure is critical for seasonal mule deer migration, although it is a recognized bottleneck. Structure is too long and narrow for elk, although some individuals documented (successful passages and repels)	Replace structure with large bridge underpass (preferred) or large arch culvert to better accommodate target species. This is an excellent location for a large dedicated wildlife crossing connecting USFS lands. Restore natural habitat under bridge. If I-70 is ultimately tunneled under the Elk Mountains to the north, ideally this segment of roadway would be entirely removed and restored. Should it remain as an access road, a bridge underpass is recommended at this site to prevent bottlenecking of migratory movements.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ F: Vail (East)

Mileposts: 176.8 – 180.1 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 3.4 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Black Bear	Boreal Toad
Elk	Moose
Mountain Lion	Northern Leopard Frog

Animal-Vehicle Collisions: Ranges from Low to Very High

Status of Adjacent Lands: Mostly private, some city land (golf course)

Site Discussion: Topography around I-70 is sloped through LIZ. There are no structures suitable for target species passage in this LIZ.

Connectivity Recommendations
Install at least one large bridge underpass and two large arch culvert underpasses to accommodate all primary and secondary target species in this LIZ. Construct limited 8' high wildlife fencing to guide animals to crossings (rather than continuous fencing through LIZ). Consider connecting structures with fencing only if they are less than 1 mile apart. When reconstructing interstate, install additional pipe culverts to accommodate passage for small and medium-sized mammals and amphibians.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
JP149	177.4	Bridge with paved road and sidewalk; intersection; frontage road immediately in front of south entrance.	Open up bridge and naturalize side slopes; add dirt or vegetated pathway. Sign at-grade crossing over parallel frontage road (stop signs at intersection keep traffic speeds low at this location)	Yes
n/a	177.8	Natural break in cliffs on north side; feeds into golf course on south side	Construct new large arch culvert or bridge underpass for lynx, deer and elk. Add limited guide fencing to direct animals to structure. Restrict human access through crossing. Requires additional mitigation at south side frontage road. Coordinate with Town of Vail (golf course).	No

JP092	179.0	Booth Creek pipe culvert channels large drainage from north. Culvert crosses under north frontage road and I-70.	Replace with larger structure, such as bridge underpass or arch. New structure should be at least 8' (preferably 10') high and 20' wide (span). Low clearance may necessitate raising roadbed.	No
n/a	179.2	Boreal toad breeding site	Coordinate with CDOW to determine if connectivity for boreal toad is needed in this area. To connect toad habitat north and south of the interstate, install specialized culverts that preserve critical ambient conditions through the culvert.	No
n/a	179.4/ .5	Least developed portion of the LIZ. Road lighting begins at interchange area immediately to east.	Install second carnivore crossing here or at JP092.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ G: Gore Creek

Mileposts: 180.9 – 182.1 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 1.3 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Black Bear	Elk
Moose	Mountain Lion
Northern Leopard Frog	River Otter

Animal-Vehicle Collisions: Moderate

Status of Adjacent Lands: Mostly private

Site Discussion: Sloped terrain. Community of East Vail extends through this LIZ south of I-70.

Connectivity Recommendations

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP089	181.0	Divided span bridge with steep slopes to north and East Vail neighborhood to south. Chain link fence across the south entrance to the bridge likely installed as a measure to keep wildlife out of the neighborhood.	Structure spans natural habitat and offers an excellent passage beneath the interstate for all types of wildlife. However, the fencing surrounding the adjacent neighborhood prevents animals from accessing additional habitat to the south. Explore opportunities with the neighborhood to develop acceptable measures that would allow wildlife to access habitat on the south side of the neighborhood, completing the north-south connection on either side of I-70. If wildlife passage through or around neighbor hood can be accommodated then install guide fencing to direct wildlife towards the structure.	No
JP063	182	Large divided span bridge over Gore Creek and Hwy 6 (dead ends). Bridge connects Forest lands, though much of LIZ is privately owned.	Concentrate human activity immediately around paved access road at west end of structure and implement measures to minimize human activity beneath the rest of the structure. Restore dirt lot/road with native vegetation cover. Requires coordination with local community and user groups to implement effective control measures and to educate the public on the importance of segregated wildlife/human uses at this location.	Yes

*Early Enhancement Opportunity

LIZ H: West Vail Pass

Mileposts: 182.9 – 188.1 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 5.3 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Elk	Moose
Mountain Lion	Mule Deer
Northern Leopard Frog	

Animal-Vehicle Collisions: Ranges from Low to Moderately-Low. Two lynx AVCs recorded in this LIZ at 187.4 and 188.7.

Status of Adjacent Lands: Public (USFS)

Site Discussion: Sloped, mountainous terrain. Black Gore Creek runs parallel to I-70 through LIZ. Zone contains multiple large span bridges that function as effective wildlife crossings for diverse species between mileposts 182.9 – 185.5. No structures are present in the eastern portion of the LIZ, from milepost 186 to 188.1.

Connectivity Recommendations
Maintain connectivity at existing bridge structures and construct new structures in eastern portion of LIZ. When reconstructing interstate, install additional pipe culverts to accommodate passage for small and medium-sized mammals and amphibians at < 0.5 mile intervals throughout the LIZ. Install wildlife fencing connecting between existing bridge structure from milepost 183 – 185.5. Add guide fencing where new structures are constructed, or, if installing continuous fencing, provide access routes through the fencing for hunters and other backcountry users.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
JP061†	183.0	Divided span bridge over small drainage. Creek (JP135) piped under bridge. There is no fencing at this site, but a retaining wall on the southeast side of the roadway and heavy traffic on I-70 act as partial barriers to at-grade crossings.	Remove culvert and restore stream channel through bridge structure. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings. If the roadway footprint increases with future highway reconstruction, the span and height of the bridge should also be increased to compensate for the additional length that animals must travel under the bridge.	Yes

JP096	184.0	Large and high divided span bridge. There is no fencing at this site, but heavy traffic on I-70 acts as a partial barrier to at-grade crossings.	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.	Yes
JP060	184.5	Large and high divided span bridge. There is no fencing at this site, but heavy traffic on I-70 acts as a partial barrier to at-grade crossings.	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.	Yes
JP059	185.0	Large and high divided span bridge. There is no fencing at this site, but heavy traffic on I-70 acts as a partial barrier to at-grade crossings.	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.	Yes
JP058†	185.5	Large and high divided span bridge. There is no fencing at this site, but heavy traffic on I-70 acts as a partial barrier to at-grade crossings. Bike path crosses under far east section of the span. Sediment pond located under structure.	Structure is highly functional for target species. Maintain connectivity at site. Complement structure with guide fencing to direct animals toward structure and discourage at-grade crossings.	Yes
n/a	186.5	Gap in cliffs on north side of roadway	Construct wildlife arch at least 12'x24' suitable for elk, deer, lynx and small and mid-sized mammals (2004 LIZ recommendation)	No
n/a†	187.4	Forest cover down to road on north side; open area to south Sediment pond on the north side of the highway.	Construct wildlife overpass	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ I: East Vail Pass

Mileposts: 191.8 – 194.2 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 2.5 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Mountain Lion	Northern Leopard Frog
River Otter	

Animal-Vehicle Collisions: Ranges from Moderate to High

Status of Adjacent Lands: Public (USFS)

Site Discussion: Divided highway with a wide, open median with West Tenmile Creek flowing through the median. Multiple large span bridges offer excellent crossing opportunities under the eastbound traffic lanes, however there are no such crossing opportunities under the westbound lanes in this LIZ.

Connectivity Recommendations
Construct structures under westbound lanes and connect new and existing structures with wildlife fencing, including median fencing. Connect fencing to existing structures outside of LIZ to west on both eastbound and westbound sides of I-70. Control gaps (for example, by installing electomats) in fencing where bike path intersects and provide recreation access through fencing at key points. Do not install continuous fencing in this LIZ before the construction of new structures that provide safe passages across westbound lanes. If continuous fencing installed, provide human access points through fencing.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
JP031†	192.0 (EB)	Large divided span bridge over small creek, for eastbound lanes only. Low, cliffy slopes opposite on westbound side.	Structure is highly functional for target species. There is no fencing at this site, but heavy traffic on I-70 acts as a partial barrier to at-grade crossings. Maintain connectivity at site and add wildlife fencing to prevent at-grade crossings from gentle slopes adjacent to bridge. Consider tying into existing structure outside LIZ to west – continuous fencing should be installed only if new crossing structures are constructed under westbound traffic lanes.	No

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
n/a†	192. 0 (WB)	At-grade with gentle, shrubby, wet drainage running perpendicular to road.	None	No
JP057	192.5-192.6 (WB)	At-grade crossing area. Gentle slopes from the north bisected by WB traffic lanes lead into drainage through median. Site is directly across from EB span bridge (JP033)	Remove fill and construct large bridge arch or bridge underpass to accommodate all primary and secondary target species at this location.	No
JP033†	192.5 (EB)	EB bridge over Stafford Creek.	Existing dry natural pathways on both side of creek. Maintain connectivity. Consider adding guide fencing or connecting to new and existing structures with wildlife fencing. Continuous fencing should be installed only if new crossing structures are constructed under westbound traffic lanes.	No
JP036	193.0 (EB)	At-grade crossing area. Mineral lick adjacent to I-70 eastbound lanes on south side	Construct a wildlife arch overpass over eastbound lanes and connect to existing structures with wildlife fencing; or given the presence of nearby existing structures on the eastbound side, in lieu of constructing a new structure here, consider directing wildlife to existing structures via wildlife fencing.	No
JP056†	193.0 (WB)	Fill slope with pipe draining small drainage bisected by westbound traffic lanes; feeds into West Tenmile Creek from the north.	Remove fill and construct large bridge or arch underpass to accommodate all primary and secondary target species at this location. Restore natural hydrologic flow regime under highway.	No
JP037	193.3 (EB)	Large divided span bridge over small creek	Structure is highly functioning for target species. There is no fencing at this site, but heavy traffic on I-70 acts as a barrier to at-grade crossings. Maintain connectivity at site. Consider connecting structure to new and existing structures with wildlife fencing.	No

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP147	193.5 (WB)	1m pipe culvert (ephemeral flows) under westbound lanes at base of fill slope on north side. Drainage across from bridge at JP037 and up from JP038 under eastbound lanes.	Provide connection across westbound lanes for wildlife using structures at JP037 & 038 by constructing a new bridge or arch underpass at this location suitable for lynx, elk, deer and moose. Add guide fencing or connect to other new structures to west with wildlife fencing. As there are no other structures to east, wildlife fencing in this direction should not extend greater than 0.5 miles, and tie back into the forest/topographic features to direct animals away from the road and prevent 'end-arounds'.	No
JP038†	193.7 (EB)	Large divided span bridge over West Tenmile Creek. Bike path crosses under far east side of the structure, on the north side of the creek.	Structure is highly functional for target species. Maintain connectivity at site. Add guide fencing or connect to other new structures to west with wildlife fencing. As there are no other structures to east, wildlife fencing in this direction should not extend greater than 0.5 miles, and tie back into the forest/topographic features to direct animals away from the road and prevent 'end-arounds'.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ J: Wheeler Junction

Mileposts: 195.2 – 195.8 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 0.7 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Moose	Northern Leopard Frog
River Otter	

Animal-Vehicle Collisions: High

Status of Adjacent Lands: Mixed public (USFS) and private

Site Discussion: No suitable wildlife crossing structures in LIZ. Much of the LIZ is occupied by the Hwy 91 interchange, where the West Tenmile Creek drainage joins the Tenmile Creek drainage. Interchange has roadway lighting on both eastbound and westbound sides. Wetlands are present on both sides of interstate and several ponds are located adjacent to the south/east side of the interstate.

Connectivity Recommendations
Construct new large bridge, arch or three-sided box culvert to accommodated primary and secondary target species as well as natural hydrologic flows and wetlands. Culvert must include a year-round dry, natural pathway for terrestrial passage. The roadbed is low relative to the surrounding landscape, and may require raising the roadbed to install a sufficiently sized culvert. Install amphibian tunnels and walls to promote amphibian movement between the wetlands.

LIZ K: Laskey Gulch

Mileposts: 207.3 – 209.0 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 1.8 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna
Elk	Very High Openness Fauna

*Secondary Target Species**

Black Bear	Moose
Mule Deer	Northern Leopard Frog

* River otter occurs in the Straight Creek drainage, but habitat is not bisected by the interstate and otter movement is not a concern in the LIZ.

Animal-Vehicle Collisions: Moderate

Status of Adjacent Lands: USFS with some private and Denver Water Board at west end of LIZ

Site Discussion: Highway parallels the Straight Creek drainage and bisects smaller drainages feeding into Straight Creek from the north; large, steep continuous fill slope on south side of interstate. Consider implications of beetle kill in adjacent forest for habitat connectivity for primary and secondary target species.

Connectivity Recommendations

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
n/a	207.7	No existing structure.	Investigate option for a second crossing structure in LIZ - arch culvert or large buried-bottom pipe culvert	No
JP021†	208.4	Large fill slope with pipe bisecting Laskey Gulch. Steep fill slope on south side drops onto flat bench.	Remove fill and construct a large divided bridge underpass to accommodate all primary and secondary target species at this location. Restore natural hydrologic flow regime under highway. Install guide fencing to direct wildlife towards structure and avert attempted at-grade crossings.	No

*Early Enhancement Opportunity
†Indicates wildlife monitoring conducted at site

Boreal Toad Breeding Site (outside of a LIZ)

Milepost: 209.5

Early Enhancement Opportunities? No

Target Species	*Species Movement Guilds*
Boreal Toad	Low Mobility Small Fauna

Status of Adjacent Lands: Public (USFS)

Connectivity Recommendations

Coordinate with CDOW to determine if connectivity for boreal toad is needed in this area to connect the breeding site to upland habitat. To connect toad habitat across the interstate, install specialized culverts that preserve critical ambient conditions through the culvert. Avoid impacts to habitat during construction, operations and maintenance.

LIZ L: Hamilton Gulch

Mileposts: 211.6 – 212.4
LIZ Length: 0.9 miles

Early Enhancement Opportunities in LIZ? No

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Black Bear	Moose
Northern Leopard Frog	

Animal-Vehicle Collisions: Moderately-Low

Status of Adjacent Lands: Public (USFS)

Site Discussion: Highway parallels the Straight Creek drainage and bisects smaller drainages feeding into Straight Creek from the north; large, steep continuous fill slope on south side of interstate. Consider implications of beetle kill in adjacent forest for habitat connectivity for primary and secondary target species.

Connectivity Recommendations
Implement at least one of the below recommended mitigation measures.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
JP019	211.7	Steep, narrow drainage with perennial flow bisected by I-70 and runaway truck ramp, creating very wide road footprint. Stream flow shoots out steeply down fill slope at outlet. Small, dirt forest road at base of fill slope on south side at base of fill slope (outlet)	No recommended action unless highway being completely realigned through this segment. If opportunity arises, move runaway truck ramp outside of LIZ (or at minimum, to uphill/east side of drainage) to reduce highway footprint immediately over the drainage. Construct large bridge to accommodate all primary and secondary target species. Restore natural hydrologic flow and stream banks through structure. Install limited wildlife fencing to guide animals to the structure, particularly on the south side of the road (drainage acts as a natural funnel on the north side). Relocate forest road at outlet so that it traverses far from the culvert entrance. Implement measures to prevent human activity at culvert.	No

JP018†	212.4	Small drainage bisected by I-70.	Primary Mitigation Site in LIZ. Construct bridge to accommodate all primary and secondary target species. Restore natural hydrologic flow and stream banks through structure. Install limited wildlife fencing to guide animals to the structure, particularly on the south side of the road (drainage acts as a natural funnel on the north side). Implement measures to prevent human activity at culvert.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ M: Bakerville

Mileposts: 216.4 – 227.1 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 10.6 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Bighorn Sheep*	Black Bear
Boreal Toad**	Elk
Mountain Lion	Northern Leopard Frog

* Coordinate with CDOW to determine whether there is a need for connectivity between Georgetown and South Clear Creek populations of bighorn sheep. May prefer to maintain barrier to sheep to contain the spread of disease. If population-level movements across I-70 are determined to be important for bighorn sheep, then a wildlife overpass is the recommended crossing type.
** Boreal toad breed sites around mileposts 217.9, 218.7 and 220.8.

Animal-Vehicle Collisions: Moderate on average. Spike at milepost 223.5. Two lynx AVCs recorded in this LIZ at mileposts 217.3 and 220.9.

Status of Adjacent Lands: Public lands (USFS) west of milepost 221; Mixed private & public (USFS & state) between mileposts 221-224; Private east of milepost 224.

Site Discussion: I-70 follows the Clear Creek drainage throughout this LIZ from the Eisenhower Tunnels to Georgetown.

Connectivity Recommendations
This is a long LIZ requiring multiple crossing opportunities for the primary and secondary target species. Construct a wildlife bridge between milepost 219.1 and 220.5 (between chain-up stations) and replace the pipe at Dry Gulch with a large arch or bridge structure. There are also opportunities to construct a large arch culvert suitable for elk & lynx in this segment (e.g., at the fill slope at milepost 221.8). Upgrade existing bridge underpass and overpasses in this segment to better accommodate wildlife. Install additional small animal pipes approximately every 1/4-mile and/or add shelves to existing drainage culverts to provide a dry pathway through these structures. Coordinate with CDOW to determine if connectivity across I-70 for boreal toad is needed in this area to connect the breeding site to upland habitat.

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP086	217.4	51" corrugated pipe at Dry Gulch	Install arch or bridge underpass at least 12'x24'. Coordinate with ARNF to amend forest plan to designate Dry Gulch as a lynx linkage (2004 LIZ recommendation).	No

JP150	217.9	Seepage feeding into wetland on north side of highway; Boreal toad breeding site	No need for aquatic connectivity at this site. This location needs to be protected as a boreal toad breeding site. If connectivity for toads to the south side of the interstate is determined to be important, then install specialized culverts that preserve critical ambient conditions through the culvert.	No
JP079	218.5	Bridge over Herman Gulch exit.	Improve wildlife passage at existing bridge structure by opening up a natural substrate pathway adjacent to the roadway to encourage nighttime use of the structure. Add signage to inform drivers of potential wildlife activity (interchange traffic is slow moving and required to stop around this structure).	Yes
n/a	218.7	Boreal toad breeding site	Coordinate with CDOW to determine if connectivity for boreal toad is needed in this area. To connect toad habitat north and south of the interstate, install specialized culverts that preserve critical ambient conditions through the culvert.	No
n/a	219.1-220.5	Forested area between chain-up stations	Construct wildlife bridge between MP 219.1 and 220.5 (between chain-up stations). Install guide fencing to direct animals towards the structure. Coordinate with the ARNF.	No
n/a	220.8	Boreal toad breeding site	Coordinate with CDOW to determine if connectivity for boreal toad is needed in this area. To connect toad habitat north and south of the interstate, install specialized culverts that preserve critical ambient conditions through the culvert.	No
JP071†	221.8	Low fill slope and gap between cliff sections on north side. Clear Creek runs parallel to south.	Dig out fill slope and/or raise the roadbed so that an arch culvert can be installed at this location. Install guide fencing to direct animals towards the structure.	No
JP102†	223.5	Bridge overpass over I-70 with 2-lane paved road. Hwy 6 frontage road immediately to south. USFS access to north.	Convert one lane of the bridge to vegetative grass/shrub cover. Investigate adding an at-grade wildlife crosswalk over Highway 6 at this location or other mechanisms to slow traffic and make drivers aware of potential wildlife crossing. Install guide fencing to direct animals away from the highway and towards the structure.	Yes
JP075	225.0	Bridge over Hwy 6 with concrete side walls and small dirt paths on either side of road.	At minimum, open up and naturalize side slopes and road shoulders to encourage nighttime wildlife use. Ultimately, replace with a bridge structure spanning the entire drainage (including creek at JP074).	Yes

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ N: Empire Junction

LIZ N: Empire Junction

Mileposts: 231.6 – 232.9 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 1.4 miles

Target Species	*Species Movement Guilds*
Canada Lynx	Adaptive High Mobility Fauna

Secondary Target Species

Bighorn Sheep*	Black Bear
Elk	Mule Deer
Northern Leopard Frog	

*East-west movement across Highway 40 is more important for Bighorn sheep than connectivity across I-70.

Animal-Vehicle Collisions: High

Status of Adjacent Lands: Mostly private, some county

Site Discussion: Confluence of two large drainages (Clear Creek and the West Fork) and junction with Highway 40. Likely these two drainages provided historical movement pathways for many species. Interchange and other infrastructure create a large barrier at this confluence. Clear Creek has forced meanders around highway infrastructure, reinforced by riprap banks throughout this segment

Connectivity Recommendations

Coordinate visioning and planning for this segment with visioning and planning for Highway 40. Preferred alternative is to construct an extensive span bridge and raised interchange through this section to accommodate terrestrial and aquatic passage between the two drainages and restore the flow of Clear Creek and its riparian banks to a more natural condition. Alternatively, construct new crossing structures at mileposts 231.2 (JP064 - just beyond west end of LIZ) and 231.6-231.9. Investigate using jersey barriers or other barrier structures to keep sheep away from I-70 road edge on north side (2004 LIZ recommendation).

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP064	231.2	Clear Creek concrete box culvert. Outside of LIZ, but possible location for a larger crossing structure.	Replace with a bridge structure and restore riparian banks. Bridge should have a wide enough span to include dry pathways for terrestrial species on both sides of the creek. Install limited guide fencing to direct animals towards structure and investigate use of scent lures to attract lynx towards structure.	No

JP066	232.3	Clear Creek concrete box culvert. Structure goes under traffic lanes and eastbound on-ramp.	None. See preferred alternative.	No
n/a	231.6-231.9	No existing structure	Identify a location to install a new large arch culvert in this segment suitable for lynx, elk, deer and bear. Install limited guide fencing to direct animals towards structure and investigate use of scent lures to attract lynx towards structure.	No
n/a	Hwy 40	No existing structure	Identify a location and construct an overpass for bighorn sheep over Hwy 40 (2004 LIZ recommendation)	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ O: Clear Creek Junction

Mileposts: 243.0 – 244.9 *Early Enhancement Opportunities in LIZ?* No
LIZ Length: 2 miles

Target Species	*Species Movement Guilds*
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Bighorn Sheep	Canada Lynx
Mountain Lion	Preble's Jumping Mouse

Animal-Vehicle Collisions: Low to Moderately-Low

Status of Adjacent Lands: Private

Site Discussion: Highway 6/Clear Creek Canyon Interchange. Western Portion of LIZ parallels Clear Creek; eastern portion ascends Floyd Hill.

Connectivity Recommendations
Land bridge over Twin Tunnels just beyond LIZ to the west. Existing bridges over Clear Creek provide little opportunity for terrestrial passage. There is a proposal in the Final PEIS to tunnel eastbound lanes from milepost 243.5 to 245.0 to remove the sharp curve at the bottom of Floyd Hill; Westbound lanes would continue on the current alignment. This tunneling option may offer the opportunity to minimize the roadway footprint through this segment.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
JP131	243.0	Divided bridge at Central City exit with additional bridges to north (exit ramp and local road). Extensive riprap under all bridges. Dirt path with 2m clearance under hwy bridges.	Open up terrestrial pathway under highway bridges (particularly on west side of creek) and restore natural stream banks. Re-design exit ramp to provide greater clearance under bridge. Facilitate at-grade crossing over local road until that bridge can also be replaced with a larger structure encompassing riparian banks and providing dry terrestrial pathways.	No
JP017	244.2	Divided bridge with concrete support walls at Hwy 6 junction. Spans Clear Creek and bike path.	Open up north side of eastbound structure by replacing walls with pillar supports. Open up and restore riparian banks on both sides of the creek (including low cover for Preble's jumping mouse). Cliffs act as natural funnel towards structure.	No

JP043†	244.9	Fill slope; Hwy 40 frontage road parallel and below interstate to north/east	Construct bridge wildlife crossing - possibly also under Hwy 40. Relocate dirt pull-out to reduce roadway footprint at this location and to discourage human activity. Install limited guide fencing.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ P: Beaver Brook

Mileposts: 245.5 – 250.2 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length: 4.8 miles

Target Species	*Species Movement Guilds*
Elk	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

Secondary Target Species

Black Bear	Canada Lynx
Mountain Lion	Northern Leopard Frog
Preble's Jumping Mouse	

Animal-Vehicle Collisions: Very High

Status of Adjacent Lands: Private

Site Discussion: I-70 is traversing through the foothills in this LIZ. Numerous fill slopes occur where the highway crosses drainages. Tall concrete median barrier (3.3' high) is present on the west side of Floyd Hill, from milepost 245.5 to the exit at milepost 246.6.

Connectivity Recommendations
Construct new crossing structures where drainages are bisected by I-70. Investigate opportunities to install a crossing structure on the west side of Floyd Hill between mileposts 245.5 and 247.5. Coordinate with local landowners and the county on zoning in this LIZ to manage zoning and development and to obtain conservation easements on key properties adjacent to new crossing structures.

Site-Specific Recommendations

Loc. #	MP	Site Description	Recommendations	EEO*
n/a	245.5	Small drainage. Open area to south, fill slope to north. Scattered homes to south	Investigate opportunity to install crossing suitable for deer and elk at this location. Consider Hwy 40 parallel to north.	No
n/a	246.5	Cut slopes just west of highway exit	Investigate opportunity to build wildlife overpass over interstate and Hwy 40.	No

JP130	247.5	North Branch Beaver Brook. Preble's occupied habitat and elk crossing area.	Primary recommended crossing location in LIZ. Replace pipe with bridge or large arch culvert and restore riparian habitat. Integrate terrestrial and aquatic crossings - structure should be large and wide enough for elk passage.	No
JP023†	248.2	Fill slope with small drainage pipe. Commercial/private lot at base of fill on N side.	Coordinate with private landowners to install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal and amphibian passage.	No
JP041	249.0	Small pipe funneling Soda Creek	Replace with more expansive bridge spanning Soda Creek, road (JP042), and riparian area. Restore and maintain riparian cover. Add wildlife fencing (and amphibian walls) to guide animals to structure.	No
JP042	249.0	Divided bridge over Soda Creek Rd	At minimum, open up riprap side slopes and restore vegetative cover along edges of road. Ultimately, replace structure with a more expansive bridge also spanning Soda Creek and restore riparian zone through structure (JP041). Add wildlife fencing (and amphibian walls) to guide animals to structure.	Yes
JP040	250.0	Large fill slope on north side; smaller fill on south side. No residences immediately adjacent.	Primary recommended crossing location in LIZ. Construct new structure either here (preferred) or MP 250.2 (JP024). Obtain easement to protect site from development. Install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal and amphibian passage.	No
JP024†	250.2	Large fill slope. Chain station above south side; residential development at base of fill to north.	Construct new structure either at MP 250 (JP040 - preferred) or here. Coordinate with private landowners to install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal and amphibian passage.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

LIZ Q: Mt Vernon Creek

Mileposts: 252.8 – 257.6 *Early Enhancement Opportunities in LIZ?* Yes
LIZ Length:

Target Species	*Species Movement Guilds*
Elk*	Very High Openness Fauna
Mule Deer	Adaptive Ungulates

*Resident herd

Secondary Target Species

Black Bear	Canada Lynx
Mountain Lion	Preble's Jumping Mouse**

**Preble's range, but no known occupied habitat

Animal-Vehicle Collisions: Very High

Status of Adjacent Lands: Private with some Denver Parks at west end

Site Discussion: I-70 is traversing through the foothills in this LIZ. Numerous fill slopes occur where the highway crosses drainages.

Connectivity Recommendations
Add limited guide fencing associated with each structure as they are constructed. If entire zone is to be fenced, then connect new structures only once they are constructed. Wildlife fencing must include controls at highway interchanges or other gaps (e.g., electromats or double cattle-guards). Primary locations for new wildlife crossing structures at mileposts 254.5, 255.3 and 257.0.

Site-Specific Recommendations				
Loc. #	**MP**	**Site Description**	**Recommendations**	**EEO***
JP097	253.4	Box culvert at Bear Gulch. Fencing enclosure for managed bison herd.	Set back park fencing and add gates leading to underpass so that they can be closed when moving the bison herd from one side of the highway to the other and left open for wildlife passage the rest of the time. Discourage cars parking above culvert on south side of interstate for bison viewing - direct all tourist traffic to north side viewing area, away from culvert. Note: adjusting the bison enclosure will allow wildlife access to the culvert, however this culvert is not large considered large enough for elk passage. It is possible, though uncertain, that the resident herd could become adapted to it, particularly given the high traffic levels on I-70. Coordinate with Denver Parks on fence design and maintain viewing area on NE side (off exit)	Yes

JP097	253.4	Same as above.	Ultimately replace the box culvert with a bridge underpass or large arch culvert suitable for elk. Tie into wildlife fencing.	No
JP026†	254.5	Steep, long fill; scattered residences to north and south	Primary recommended crossing location in LIZ. Coordinate with private landowners to install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal passage.	No
JP027; JP022†	255.3	Steep fill slope (JP027) with small pipe at base of fill (JP022). Hwy 40 fill slope located to north.	Primary recommended crossing location in LIZ. Coordinate with private landowners to install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal passage.	No
JP001	256.0	Large fill slope with small box culvert funneling Mt Vernon Creek. Paradise Rd. immediately to North. Area has extensive exurban development.	Secondary site. Coordinate with private landowners to install bridge or large arch culvert to facilitate deer and elk passage. Add wildlife fencing to guide animals toward structure. Include woody debris cover along one side of the structure to facilitate small mammal passage.	No
n/a	256.6	Large fill slope at Hwy 6 on north side; drops into Mt Vernon Creek on south side.	Install bridge structure under Hwy 6 and I-70 to accommodate deer and elk. Include woody debris cover along one side of the structure to facilitate small mammal passage. Investigate opportunities to obtain conservation easements around crossing.	No
n/a	257.0	Low fill, rolling hills on north side; steep slope to creek on south side. Hwy 6 parallels to north. No development in vicinity.	Primary recommended crossing location in LIZ. Install bridge structure under Hwy 6 and I-70 to accommodate deer and elk. Include woody debris cover along one side of the structure to facilitate small mammal passage. Investigate opportunities to obtain conservation easements around crossing.	No

*Early Enhancement Opportunity

†Indicates wildlife monitoring conducted at site

AQUATIC CONNECTIVITY RECOMMENDATIONS (Fish Passage)

*Target species not listed. Contact CDOW for species-specific information.
**Indicates Early Enhancement Opportunity. Before implementing enhancements, confirm target species presence in sites currently listed as 'unknown'.
†Whirling disease is present in many streams indicated.

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Colorado River†	JP051	133.5	Unknown	No	Divided Bridge. Dirt parking lots on both east and west sides. Parallel bridge to north for county road has low clearance over riparian banks.	Maintain aquatic connectivity at site including natural stream channel and stream banks. While site is not in a LIZ-2011, it offers an excellent opportunity for terrestrial connectivity as well. Minimize riprap along banks and concentrate human activity at a designated put in/take out site.	No
Eby Creek†	JP136	146.4	Unknown	No	5' diameter corrugated pipe. Inlet inaccessible. Feeds directly into Eagle River at outlet; presumed outlet drop at lower water levels.	Replace with larger box, arch, open-bottomed pipe or embedded pipe culvert and lower the culvert height to allow fish upstream access to wetland habitat on north side of interstate.	No
Eagle River†	JP116	154.0	Unknown	No	Divided Bridge over Eagle River, Hwy 6 & RR. Continuous substrate and shallow banks through structure.	Maintain aquatic connectivity at site and integrate terrestrial connectivity measures.	No
Eagle River†	JP114	158.7	Unknown	No	Divided Bridge. Continuous substrate and shallow banks through structure.	Maintain aquatic connectivity at site and integrate terrestrial connectivity measures. Monitor bank erosion and implement upstream and downstream stability measures as needed.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Red Canyon Creek†	JP113	159.4	Unknown	No	Corrugated pipe with perennial flow. Channel was rerouted (90 degree angle) for roadway. Pooling at inlet due to debris accumulation and culvert skew. 1.6' drop at outlet and fencing across outlet and second pipe downstream under railroad.	Confirm presence of target species and establish connectivity need. Preferred solution: Replace the existing pipe and box culvert at JP112 with a bridge over the road and stream and restore the entire riparian channel. Alternate option: Install a new, larger culvert (e.g., oversized open bottomed pipe) more consistent with the natural stream channel slope and alignment. Restore stream channel and maintain natural substrate through the new culvert; Construct a series of navigable pools & steps through both the Hwy culvert and the RR culvert (which likewise should be replaced with a larger culvert). Include a low-flow channel to maintain sufficient water depth through the culvert year-round.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Beard Creek†	JP110	161.9	Unknown	No	5.6' diameter corrugated metal pipe at base of fill slope. Outlet perched with 13' drop to channel, which flattens out beyond the outlet through a wide, agricultural floodplain.	Coordinate with CDOW to determine whether the natural stream grade is a natural barrier to connectivity between the Eagle River and Beard Creek upstream from the Eagle River floodplain. Culvert slope, even if replaced, likely too steep for fish passage. If connectivity is desirable at this location, replace with large 3-sided box, arch, open-bottomed pipe or embedded pipe culvert. Implement upstream and downstream grade-control measures and identify an appropriate culvert slope to remove drop and mimic channel conditions through the culvert to improve passage.	No
Berry Creek†	JP137	162.7	Yes	Yes	Creek realigned 90 degrees and funneled into large culvert and then drops - distance unknown. Large trash rack over inlet (some debris accumulation at time of inventory). Upstream culvert under local road. Outlet not found (among buildings or directly channeled into Eagle River).	Coordinate with CDOW to determine if connectivity desirable at the road-stream crossing. Replace existing culvert with shorter culverts and restore stream channel to confluence with Gore Creek. Criteria include: minimizing culvert length, removing drop(s) and restoring a more natural grade, mimicking the natural range of velocities inside the culvert, and providing rest areas for fish moving upstream through the culvert. Daylight a long culvert as needed.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Buck Creek †	JP138	166.3	Unknown	No	6' diameter pipe. Meanders into wing wall. Culvert grade largely consistent with channel grade - sediment in culvert at outlet. Channel continues between buildings/lots, and retains stream banks and meanders.	Build up grade coming into inlet so that water flow doesn't have to 'jump' into culvert. Add substrate inside culvert and secure by constructing baffles or weir plates inside the culvert.	Yes
Nottingham Gulch†	JP101	168.0	Unknown	No	Pipe culvert. Inlet is a drainage slot, with large stormwater control structure. Culvert channeled under I-70, frontage road, Home Depot parking lot, RR and secondary road. Flow restriction structure at outlet to limit stormwater inputs into Gore Creek	Replace hard stormwater control infrastructure with a wetland on the north side of I-70 (inlet) and build constructed wetland on the south side of I-70 before the outlet to control runoff inflows. Use soft bioengineering techniques in lieu of flow restriction devices to control inflows into Gore Creek from Nottingham Creek and surrounding impervious surfaces. Replace pervious pavements with impervious pavements to control runoff. Replace structure with a series of shorter structures.	No
Eagle River†	JP049	168.7	No	No	Large, divided span bridge over Eagle River, railroad and Hwy 6. Some bank armoring (support wall) and riprap.	Maintain connectivity at site including natural stream channel and stream banks. Minimize riprap and maintain shallow banks.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Eagle River†	JP047	171.1	No	No	Divided span bridge at Minturn Exit. Road on west side of channel; railroad on east side. Substantial riprap along banks through structure and upstream/downstream. Second bridge immediately downstream.	Maintain connectivity at site including natural stream channel and stream banks. Minimize riprap and maintain shallow banks.	No
Gore Creek†	JP046	171.3	No	No	Bridge over Gore Creek and bike path. Deep channel with extensive riprap.	Maintain connectivity at site including natural stream channel and stream banks. Minimize riprap and maintain shallow banks.	No
Unknown Tributary to Gore Creek†	JP139	172.9	Yes	No	42" pipe. Wildlife fence runs 10' in front of inlet w/ debris built up along base of fence. Sediment in culvert at inlet. Drops into riprap cascade on banks of Gore Creek at outlet.	Replace culvert with an oversized box, arch or pipe so that the outlet invert is at the elevation of Gore Creek at low flow. Reroute wildlife fencing so that it does not block culvert inlet.	Yes
Buffehr Creek†	JP095	174.0	Unknown	No	75" diameter corrugated metal pipe. Culvert skew and concrete apron at inlet; apron at outlet, cascades into rocky, stabilized channel. Inadequate.	Improve transition into culvert by creating a step-pool system through culvert, including a low-flow channel. Consider downstream improvements such as rock weirs.	Yes
Red Sandstone Creek†	JP094	175.0	Yes	No	83" diameter corrugated metal pipe. Inlet and outlet skewed relative to stream channel. Drops on to concrete apron at inlet. Cascade at outlet into deep pool.	Add rocky step-pool system through culvert and at inlet to control high water velocities and provide resting areas inside the culvert. Include a low-flow channel in the retrofit design. Ultimately, install a new, larger culvert (e.g., oversized open bottomed pipe) more consistent with the natural stream channel slope and alignment. Restore natural stream channel and maintain natural substrate through the new culvert.	Yes

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Middle Creek†	JP093	175.8	No	No	~118" diameter corrugated metal pipe. Pipe skewed relative to road and stream channel (inlet and outlet). Flow cascades into inlet through trash rack. Small drop into pool at outlet. Outlet is slightly crushed in; sediment filled, reducing effective culvert height to 1/2 of inlet height. Indeterminate.	None – no target species present.	No
Spraddle Creek†	JP140	176.0	Yes	No	Concrete water slide into grated pipe culvert, then drops into abyss. Thick willow riparian channel upstream. Culvert runs under Spraddle Creek Road, exit ramp, interstate and Town of Vail on south side. Outlet unknown.	To restore connectivity at this location, culvert must be replaced with large 3-sided box, arch, open-bottomed pipe or embedded pipe culvert. Minimize culvert length (several shorter culverts as opposed to one long one); implement upstream and downstream grade-control measures and identify an appropriate culvert slope to remove drop and mimic channel conditions through the culvert to improve passage.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Booth Creek†	JP092	179.0	Yes	Yes, upstream barrier	Oblong (122x79") corrugated pipe at inlet; About 10' into culvert, pipe slopes steeply down. Pipe size much smaller at outlet. Small drop into pool at outlet. Culvert skewed relative to stream channel and road. Long culvert under I-70 & frontage road.	Coordinate with CDOW to determine if connectivity desirable between the Eagle River and the lower portions of Booth Creek (to upstream barrier). Install a new, larger culvert (e.g., oversized open bottomed pipe) more consistent with the natural stream channel slope and alignment. Design culvert to be as short as possible and, ideally, install two separate culverts under the interstate and the frontage road. Build natural substrate through the new culver and construct a series of navigable pools & steps through the culvert; include a low-flow channel to maintain sufficient water depth through the culvert year-round. Daylight a long culvert as needed.	No
Pitkin Creek†	JP141	180.0	Yes	Yes	Pipe culvert. Sloped inlet with wing wall and headwall. Inlet-to-channel width ratio 1:2. 3.3’ drop at outlet into 5x4m pool.	CDOW maintains intentional barriers to protect upstream conservation population. Coordinate with CDOW to determine if connectivity for other aquatic organisms is desirable at this road crossing location.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Bighorn Creek†	JP090	180.6	Unknown	No	63" diameter corrugated metal pipe. Skewed at inlet and relative to roadway. Flow drops ~3' onto concrete apron at inlet. Cascade onto riprap and into pool at outlet. Second culvert under local road downstream. Inadequate.	Remove barrier at inlet and allow substrate to fill the bottom of the culvert and restore natural grade into inlet. Ultimately, replace culvert with large 3-sided box, arch, open-bottomed pipe or embedded pipe culvert. Maintain a grade through the culvert that is consistent with upstream and downstream conditions. Construct features to mimic channel conditions through the culvert and improve fish passage. Coordinate with local municipality to ensure continued connectivity through downstream culvert.	Yes
Gore Creek†	JP063	182.0	Yes	No	Large divided span bridge.	Maintain connectivity at site including natural stream channel and stream banks.	No
Black Gore Creek†	JP062	182.5	Yes	No	Divided bridge over steep, narrow drainage.	Maintain connectivity at site including natural stream channel and stream banks.	No
Unknown Tributary to Black Gore Creek†	JP135	183.0	Yes	No	3.3' diameter culvert piped under bridge structure (JP061). Culvert is heavily skewed relative to road. Outlet drops onto metal apron and 2.5m pool. Metal wing wall at outlet broken and leaning across outlet. Inlet inaccessible, surrounded by willows.	Remove culvert and restore stream channel under bridge structure at JP061.	Yes

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Unknown Tributary to Black Gore Creek†	JP134	183.3	Yes	No	4.5' pipe; step-pool system. Channel somewhat wider than culvert.	Install shallow weir plates through culvert to reduce water velocities and add roughness. Ultimately, install a new, larger culvert (e.g., oversized open bottomed pipe) to encompass the channel's bankfull width. Construct features that mimic channel conditions through the culvert and improve fish passage.	Yes
Timber Creek†	JP096	184.0	Yes	No	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No
Black Gore Creek†	JP060	184.5	Yes	No	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No
Miller Creek†	JP059	185.0	Yes	Yes, upstream (natural)	Large divided span bridge over natural riparian channel. Natural upstream barrier maintained to protect conservation population.	Maintain connectivity at site including natural stream channel and stream banks.	No
Polk Creek†	JP058	185.5	Yes	Yes, upstream	Large divided span bridge over natural riparian channel.	CDOW maintains intentional barriers upstream to protect upstream fish population. Coordinate with CDOW to determine if connectivity for other aquatic organisms is desirable at this road crossing location.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
West Tenmile Creek	JP148	190.3 (EB)	No	No	94" embedded pipe. Stream alignment forced through culvert causing pooling and erosion above inlet and pushing wing wall in. Structure crosses under hwy and bike path.	Implement upstream bank stabilization measures to reduce bank erosion and alleviate wing wall failure. When structure is replaced, widen structure or install a curved culvert to minimize forced changes in flow direction that undermine structure integrity.	No
Wilder Gulch	JP029	190.8 (EB)	Unknown	No	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No
Unknown Tributary West Tenmile Creek	JP030	191.2 (EB)	Unknown	No	40" diameter corrugated metal pipe. Inlet and outlet metal aprons and wing walls. Inlet wing wall is crushed in.	Repair crushed flared end section at inlet. Install weir plates and add gravel substrate inside culvert; construct step/pool features at outlet.	Yes
Corral Creek	JP028	191.3 (WB)	Unknown	No, but potential location for a barrier	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No
Unknown Tributary West Tenmile Creek	JP127	191.5 (EB)	Unknown	No	49" diameter corrugated metal pipe under eastbound lanes only (feeds into W. Tenmile Creek in median)	Construct drop/pool structures.	Yes
Smith Gulch	JP031	192.0 (EB)	Unknown	No	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Unknown Tributary to West Tenmile Creek	JP032	192.0 (EB)	Unknown	No	36" diameter corrugated pipe. Inlet & outlet aprons & wing walls. Some pooling at inlet. Creek flows into West Tenmile Creek in median. Indeterminate.	Install weir plates at inlet and through structure to control flow velocities and retain gravel substrate.	Yes
Stafford Creek	JP033	192.5 (EB)	No (historical trout pop.)	No, but potential location for a barrier	Large divided span bridge over natural riparian channel. Stafford Creek is on record as having cutthroat trout, but there are no recent data.	Maintain connectivity at site including natural stream channel and stream banks. This tributary should be highlighted as a potential place to introduce a barrier if identified as a need after surveys are conducted.	No
Unknown Tributary to West Tenmile Creek	JP056	193.0 (WB)	Unknown	No	40" diameter corrugated metal flat-bottomed pipe. Steep long culvert, slope flattens at outlet. Culvert heavily skewed relative to stream channel at inlet. Shallow flow disperses over apron at inlet during low-flow periods. Sediment buildup at outlet.	Narrow channel at inlet to create deeper pool and increase flow depth over inlet apron. Coordinate terrestrial and aquatic connectivity needs and, ultimately, remove fill and construct a large bridge or arch underpass. Restore natural hydrologic flow regime under highway.	Yes
Guller Creek	JP037	193.3 (EB)	Unknown (historic trout pop.)	No, but potential location for a barrier	Large divided span bridge. Guller Creek is on record as having cutthroat trout, but there are no recent data.	Maintain connectivity at site including natural stream channel and stream banks. This tributary should be highlighted as a potential place to introduce a barrier if identified as a need after surveys are conducted.	No
West Tenmile Creek	JP038	193.7 (EB)	Unknown	No, but potential location for a barrier	Large divided span bridge over natural riparian channel.	Maintain connectivity at site including natural stream channel and stream banks.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Officer's Gulch	JP146	198.0	No	No	60" pipe. Drop into inlet. Debris collection at trash rack across inlet causing water to pool. Upstream pedestrian bridge at lake outlet also has debris collection. Outlet has extensive wing walls and pooling (water flow eddies back into wing wall).	Lower invert of channel so that it is at the same elevation as the inlet of the pipe, thus creating a deeper pool. Redesign trash rack such that debris accumulates on the surface of the pool and water can flow through the rack from the pool and into the inlet without dropping. Maintain regularly to remove debris accumulation at trash rack.	No
Unknown Tributary to Tenmile Creek	JP145	199.0	Unknown	No	Two 32" culverts situated in a long concrete headwall. Culverts heavily skewed relative to stream channel and there is extensive pooling at inlet and outlet.	Replace undersized culverts with a single large culvert wide enough to encompass the stream and floodplain and natural stream alignment to remove forced changes in flow direction.	No
North Tenmile Creek	JP035	200.9	No	No, but potential location for a barrier	11x10' concrete box culvert. Drop over concrete apron into culvert with fish ladder (unknown effectiveness).	Coordinate with CDOW - if trout are reintroduced upstream an intentional barrier may be installed and connectivity may not be needed at this location. Redesign the fish ladder with longer pools spread out over a greater distance to improve resting areas.	No
Meadow Creek	JP144	201.9	Yes, upstream	Yes, upstream waterfall	40" culverts (separate culverts under EB and WB lanes with open, vegetated median); concrete headwall and wing walls. Culverts undersized for heavy flows.	Coordinate with CDOW on upstream trout conservation.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Salt Lick Gulch	JP039	204.5	Unknown	No	45" corrugated metal pipe. Smooth plastic at inlet, corrugated metal at outlet. 15" drop onto riprap at outlet and into pool. Stream crosses under I-70 again downstream at JP143.	Coordinate with CDOW to determine priority, given lack of connectivity downstream to Blue River at culvert under access road (note target species present in Blue River). Construct a series of drop/pools at the outlet to remove drop.	Yes
Salt Lick Gulch	JP143	205.0	No	No	60" pipe, 0.5 mile downstream from road-stream crossing at JP039. Extensive, deep pooling at inlet; metal culvert pulling away from concrete headwall at inlet. Culvert drops under highway, flattens out at outlet. Extensive pooling at outlet. Channel has been realigned between highway and Wildernest Rd at outlet, creating major skew. Creek then crosses secondary road (with concrete slide drop at inlet) before feeding into Blue River.	None – target species not present and lack of connectivity downstream to Blue River at culvert under access road.	No
Blue River	JP034	205.3	No	No	Divided bridge over river, frontage road, bike path and dirt access road. Continuous substrate and shallow banks through structure. Adjacent parallel bridge for local road has low clearance and no shallow banks under bridge.	Coordinate with local municipality on infrastructure planning. Maintain connectivity at site.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Laskey Gulch	JP021	208.4	Yes	No	60" corrugated metal pipe at base of large fill slope, 20" drop into large pool at outlet. Outlet pool then drops 40" at headgate into stream channel	Determine if in-stream barrier needed. Replace culvert with large span bridge. Integrate terrestrial and aquatic connectivity needs. Restore natural hydrologic flow regime under highway.	No
Hamilton Gulch	JP019	211.7	Unknown	No	43" corrugated metal pipe - runs under runaway truck ramp and interstate. Extremely steep grade. Some debris present at inlet (trees); slope flattens out to a more natural grade >50m from outlet. 60m from outlet are twin smaller culverts underneath a forest road.	Replace culvert with bridge structure (integrate with terrestrial recommendation) and restore step/pool system.	No
Unknown Trib Straight Creek	JP018	212.4	Unknown	No	43" corrugated plastic pipe. Steep culvert slope. Heavy, fast flows at time of inventory.	Integrate terrestrial and aquatic connectivity needs. Restore natural hydrologic flow regime under highway.	No
Straight Creek	JP142	213.5	Unknown	No	4' diameter pipe culvert. Headwall, pooling at inlet. Inlet-channel width ratio 1:3. Stream drops steeply into inlet and crosses under CDOT buildings, I-70 and large paved area at west entrance to Tunnels.	None.	No
Dry Gulch	JP086	217.4	Yes, upstream	Yes	51" corrugated plastic pipe with steep concrete apron and wing walls at inlet. Projects into pool at outlet. Dry Gulch has a very high gradient stretch just north of I-70 continuing north up to a valley bench where the valley flattens out and where the greenbacks are located. This high gradient section needs to be maintained to protect the pure trout.	Maintain grade barrier to protect upstream trout conservation population.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Herman Gulch	JP078	218.5	Yes	No	70" corrugated metal pipe under exit ramp and traffic lanes. Trailhead access bridge immediately upstream. Flows over steep concrete apron into inlet.	At minimum, add weir plates on inlet apron to create drop-pool structure. May add weir plates through structure as well. Maintain step pools at outlet. Ultimately, replace with an oversized bottomless culvert and restore natural channel and banks.	Yes
Watrous Gulch	JP077	219.4	Yes	No	Metal pipe under I-70 and eastbound and westbound chain stations. Steep, incised channel upstream, pools as grade flattens in front of culvert at inlet (embedded). 3' drop into small pool at outlet.	Replace with an oversized bottomless culvert that mimics the natural channel grade to eliminate drops and pooling.	No
Unk Trib Clear Creek	JP072	221.4	Yes	Yes, upstream waterfall	40" corrugated metal pipe. Second culvert upstream at top of waterfall under frontage road. Feeds immediately into Clear Creek at outlet.	None. Very high gradient tributary does not provide trout habitat. Downstream barriers on Clear Creek.	No
Thompson Gulch	JP133	222.8	Yes	No	40" corrugated metal pipe. Steep, rocky drop into concrete-reinforced inlet. Wing wall, pooling at inlet. Outlet inaccessible.	None. Very high gradient tributary does not provide trout habitat. Upstream and downstream intentional barriers on Clear Creek.	No
Brown Gulch	JP076	224.9	Yes	No	60" metal pipe - inlet is slot drain. Steep drainage upstream. Cascade onto riprap at outlet feeds directly into Clear Creek.	None. Very high gradient tributary does not provide trout habitat. Upstream and downstream intentional barriers on Clear Creek.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Clear Creek	JP074	225.0	Unknown	No	16x8.5' angled concrete box culvert. Riprap banks upstream and downstream. Small box culvert under frontage road about 300' from inlet.	Maintain connectivity at site. Ultimately, replace with wider culvert and restore natural channel alignment. Preferred alternative is to integrate terrestrial and aquatic connectivity needs by replacing culvert and bridge at JP075 with a longer bridge spanning the entire drainage and roadway.	No
Clear Creek	JP132	225.9	Yes	No	13x6.5' concrete box culvert. Heavily skewed from channel, 1:2 inlet-channel width ratio. Water velocities through structure may present a barrier to fish passage at high water levels.	Reduce water velocity through structure. Restore a more natural channel alignment and replace with a new, larger structure that can accommodate the bankful channel width.	No
Unk Trib Clear Creek	JP070	227.0	No	Yes, upstream waterfall	35" smooth metal pipe at inlet, corrugated metal at outlet. Steep culvert grade. Feeds onto concrete channel at outlet.	None. Very high gradient tributary does not provide trout habitat.	No
Silver Gulch	JP065	228.2	Unknown	No	45" corrugated metal pipe. Inlet heavily skewed relative to channel. Cascade over riparp into inlet. Sediment buildup at outlet. Substrate may provide spawning gravel for brown trout inhabiting adjacent areas of Clear Creek.	Remove drop at frontage road by cutting back the culvert and creating a step/pool system. Ultimately, replace and lower the culvert.	Yes

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Clear Creek	JP064	231.2	No	No	30x9.5' double box culvert. Culvert is skewed relative to channel and road. Forced changes in flow direction cause backwatering and pooling. Riprap banks at inlet and outlet. Flow drops into culvert at inlet	None - target species are not known to be present.	No
Clear Creek	JP066	232.3	No	No	26x8.5' double box culvert under traffic lanes and on-ramp. Entire segment of Clear Creek has been realigned to accommodate the interstate. Slopes reinforced with riprap throughout segment.	Integrate terrestrial and aquatic connectivity needs. Preferred alternative is to construct an extensive span bridge and raised interchange through this section to accommodate terrestrial and aquatic passage between the two drainages and restore the flow of Clear Creek and its riparian banks to a more natural condition.	No
Mill Creek	JP068	234.8	No	No	10x8.5' concrete box culvert. Long, steep apron into inlet. Bridge over frontage road immediately upstream. Concrete walls line the banks of this section of the creek. Natural substrate into inlet. Substrate continuity through 3/4 of structure; last 1/4 is concrete. The culvert does not appear to currently present a major barrier to fish passage.	Connectivity is not a priority at this location because no target species are known to be present in this tributary. Ultimately, replace concrete pan at frontage road bridge with low-flow cobble channel to dissipate energy and allow fish and other aquatic organisms to navigate upstream. Add boulders to outlet of box culvert to dissipate energy and add habitat. Replace long apron at inlet with a series of low-flow step pools and build up culvert outlet to remove drop.	No
Spring Gulch	JP005	236.2	No	No	67" partially embedded corrugated metal pipe. Sediment buildup and dumping at inlet. Slope drops steeply at outlet into Clear Creek.	None.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Fall River	JP003	237.7	Unknown	No	10x10' box culvert. Small drop at culvert inlet, some backwatering at inlet and outlet.	Maintain connectivity at site.	No
Clear Creek	JP009	239.9	No	No	Bridge, riprap bank armoring. Resembles natural channel.	Maintain grade control in Clear Creek. Maintain connectivity at site.	No
Soda Creek	JP008	240.1	Unknown	No	102x118" corrugated metal pipe. Rocks placed inside culvert. Creek goes under lumber yard at outlet (smaller culvert, but nicely entrenched), channelized until it reaches Clear Creek.	None. Coordinate with local municipality, lumberyard and other downstream property owners for future reconstruction.	No
Clear Creek	JP016	241.8	No	No	Bridge - resembles natural channel	Maintain grade control in Clear Creek. Maintain connectivity at site.	No
Clear Creek	JP011	242.9	Unknown	No	Bridge - resembles natural channel. Downstream bridges.	Maintain grade control in Clear Creek. Maintain connectivity at site. When bridge replaced, restore shallow banks under bridge.	No
Clear Creek	JP131	243.0	No	No	Divided bridge; additional bridges to north for exit ramp and local road. Very little natural bank areas.	Maintain grade control in Clear Creek. Maintain connectivity at site. Coordinate with local road department to ensure ongoing connectivity through all structures. When bridge replaced, integrate terrestrial and aquatic connectivity needs, including the restoration of riparian banks through the structure.	No
Clear Creek	JP017	244.2	No	No	Divided span bridge with concrete support walls.	Maintain grade control in Clear Creek. When bridge replaced, integrate terrestrial and aquatic connectivity needs, including the restoration of riparian banks through the structure.	No

STREAM NAME	LOC #	MP	TARGET SPECIES*	INTEN-TIONAL BARRIER	SITE DISCUSSION	CONNECTIVITY RECOMMENDATIONS	EEO**
Beaver Brook	JP130	247.5	Unknown	No	55” pipe culvert. More water flow at outlet than at inlet. Culvert must have bend under highway and have other sources flowing into it. Extensive woody debris in front of inlet. Inhabited by small-bodied fish. Outlet apron creates a barrier to fish passage.	Integrate terrestrial and aquatic connectivity needs. Replace with bridge or arch and restore banks and riparian habitat. Restore a more natural stream alignment (no sharp bends).	No
Soda Creek	JP041	249.0	Unknown	No	45" corrugated metal pipe. Some sediment deposition in culvert and fill eroding above culvert at inlet. 28" drop at outlet into pool. Culvert is a major barrier for the small-bodied fish that inhabit this stream.	At minimum, replace with a bottomless culvert and construct step/pool structures to eliminate drops. Preferred alternative is to integrate terrestrial and aquatic connectivity needs. Replace with a bridge structure and restore natural stream channel and riparian banks.	Yes
Mt Vernon Creek	JP001	256.0	Unknown	No	7.9x6.2' box culvert at base of large fill slope. Steep drop into culvert at inlet. Flow through culvert is wider and shallower than upstream channel. Outlet partially buried with sediment and debris. Large pool at outlet with weir and water diversion structure.	Reduce the width to depth ratio and install habitat enhancement measures, such as adding weirs at inlet and through culvert to provide velocity control and a low-flow channel through the culvert. Identify water rights holder and determine if water diversion in use; if possible, remove water diversion at outlet.	Yes

APPENDIX F

Guidelines for Improving Connectivity for Terrestrial and Aquatic Wildlife on the I-70 Mountain Corridor

I. CONSIDERATIONS FOR TERRESTRIAL PERMEABILITY

Medium and Large-Sized Box or Arch Culverts and Bridges

A) CREATE OR MAINTAIN FUNCTIONAL WILDLIFE CROSSINGS FOR MEDIUM-SIZED AND LARGE ANIMALS AT AN AVERAGE INTERVAL OF 1 MILE OR LESS ALONG THE I-70 MOUNTAIN CORRIDOR, DEPENDING ON ANIMAL MOVEMENT PATTERNS, TOPOGRAPHY AND HABITAT FEATURES TO PROVIDE PASSAGES FOR MEDIUM AND LARGE-SIZED ANIMALS. TO ACCOMPLISH THIS:

1. Where a drainage structure (culvert, concrete box culverts (CBC) or bridge) is needed as part of the highway system, install, modify or maintain existing drainage structures to accommodate wildlife movement

Where terrain permits and where it is practical:

a) Install the largest bridge (preferably) or culvert practicable for any given location or terrain.
b) Replace a bridge with a bridge of equal size or larger. Replace a culvert with a bridge, arch culvert, box culvert, or buried-bottom pipe of equal size or larger.[1]
c) Install the shortest structure practicable for a given roadway width, while maximizing structure width (span) to maximize openness and avoid a 'tunnel effect'. Make structures wider rather than taller. Wide underpasses allow animals to have a broad viewing area, which makes them feel less vulnerable.
d) Consider two shorter underpasses with a median or 'atrium' instead of one long structure under four or more traffic lanes.
e) Ensure visibility from one end of a structure to the other.

[1] For species-specific design and dimensional specifications, use the following references:
Clevenger, A. P. and M. P. Huijser. 2011. Wildlife crossing structures handbook: design and evaluation in North America. Federal Highway Administration Report No. FHWA-CFL/TD-11-003. Lakewood, CO. [see Chapter 4]
Kintsch, J. and P. Cramer. 2011. Permeability of existing structures for wildlife: developing a passage assessment system. Washington Department of Transportation Report No. WA-RD 756.1. Olympia, WA. [see Tables 1 & 2]

f) Maintain a natural substrate underneath the bridge. If concrete is necessary to prevent scour, then it is recommended to cover the concrete with a natural substrate. Install baffles to retain sediment and prevent scour.
g) Use flooring of native material. For passages with perennial or ephemeral water flow, design structures to be wide enough to provide a dry pathway at least 3' wide for animals to use on one or both sides of the waterway.
h) Engineer structures to minimize traffic noises for animals inside of or at the entrance to a structure (e.g., use noise-absorbing surfaces inside underpasses to reduce resonating noise, and/or use quiet pavement to reduce the extent of a road's noise disturbance zone).
i) Limit roadway lighting where crossing structures are located.
j) Use vegetated 'green screens' or other mechanisms along the sides of over-crossings to reduce highway noise and lights from animals on the structure.
k) Solid bridge railings should be installed immediately above under crossings to reduce highway noise and lights for animals crossing below.
l) Remove barriers at structure entrances that could prevent wildlife passage including, fencing or gates, boulders, rip-rap, or provide a pathway for wildlife through the obstruction.
m) Maintain or restore native vegetation immediately adjacent to the structure at each entrance to encourage wildlife activity, provide natural cover and filter traffic light and noise. Use native vegetation seed to encourage wildlife use, promote establishment and suppress weedy species.
n) Avoid using rip-rap or boulders to maintain aprons at the culvert entrances as these may be difficult for hooved animals to negotiate. If a rip-rap apron must be used, consider placing topsoil over the rip-rap along the edges so as to create a natural path or game trail.
o) Design passage characteristics for both mobile species as well as limited-mobility species (e.g., pile up stumps or boulders along the inside wall of a large underpass to provide small mammal cover).

2. Locate additional structures at points where "Linear Wildlife Guideways" intersect I-70, where wildlife prefer to cross

Linear Wildlife Guideways are natural travelways defined as topographical ridges or drainages, sharply delineated changes in vegetation, or vegetation forming a peninsula. The intersection of a linear guideway with a roadway often creates a well-defined, intensely used crossing zone.

a) Maintain vegetated ridges and drainages or other sharply defined changes in vegetation inside, and if possible outside the Right of Way.
b) Use fencing to direct animals toward underpass crossings and away from road approaches.
c) Reduce distance to cover by maintaining natural vegetation around the inflow and outflow of drainage structures, preferably in the form of vegetated peninsulas.
d) Secure lands adjacent to crossing structures for long-term habitat protection.

3. Construct CBCs and bridges using natural colors and textures

a) Construct sloped side supports instead of vertical walls. Use the lowest angle possible and natural substrate for abutment slopes.
b) If support slopes are steep and/or rip-rap must be used for abutment slopes, construct a flat, dry pathway at least 5' wide cut into each slope.
c) Use open support pillars instead of walls for structures with a long span.
d) Avoid the use of mesh erosion control netting, which may ensnare snakes.

4. Design and maintain fencing to prevent wildlife from crossing at high-risk areas and to lead them to Wildlife Road Crossings

a) Fencing for large mammals should be at least 8' high, with a mesh size less than 10cm x 15cm, without gaps between the fence and the ground and, where required to prevent animals from digging underneath, seated at least 15cm into the ground. [2]
b) Avoid constructing fencing for > 1 mile without providing suitable safe crossing opportunities.
c) Fencing should be placed the entire length between structures and in medians between culvert/bridge openings to prevent animals from entering the roadway from the median.
d) Ensure that fencing is fully connected to structures without gaps.
e) Minimize "natural ladders" adjacent to the fence which could facilitate an animal climbing over the fence (e.g. trees, large bushes, etc.).
f) Construct and/or reposition wildlife fencing such that all culvert outlets (large and small culverts) are located outside of the ROW.
g) Construct escape ramps at regular intervals to provide escape routes for animals trapped inside of the ROW.
h) Use control mechanisms such as double cattle guards and electric mats to prevent animals from entering the ROW through gaps in the fencing (e.g., at interchanges).
i) Curve fence ends back into the landscape away from the ROW and/or use boulder piles at fence ends to discourage wildlife from crossing the roadway at fence ends.
j) Provide human access through fencing in areas where access is important to prevent people from damaging the fencing (e.g., ladders over the fencing, small angular passageways through the fence where a human could walk through but an animal could not, or, for private land access only, gates).

[2] For fencing specification, refer to:
California Department of Transportation Wildlife Crossing Guidance Manual (p. 61):
http://dap3.dot.ca.gov/hq/env/bio/wildlife_crossings/
Arizona Department of Transportation Wildlife Funnel Fencing Summary:
http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf

5. Where guard rails, regaining walls or jersey barriers or steep road cuts are required, keep in mind that barrier ends tend to funnel animals onto the roadway

a) Locate the ends of barriers where there is a good line of sight to give motorists adequate time to avoid animals that enter the roadway at these locations.
b) Consider locating wildlife crossings at the end of barriers where appropriate, based on wildlife movement patterns, topography and habitat features.

6. Avoid offsetting culverts and bridges where multiple structures are needed under a divided highway or where two roads run parallel to one another so that animals have a straight line of sight through all of the structures

7. Install features to minimize or prevent human use of wildlife crossing structures such as signs or barriers at potential access points

8. Install bird poles along wetlands or bridges to force birds to fly higher over the roadway

9. Add features to bridges to promote day and night roosting for bats, where appropriate

a) To function as day roosts, bridges should be greater than 10’ above the ground, have vertical crevices 0.5 to 1.25” wide, have vertical crevices 12 inches or greater in depth, be sealed from rainwater and debris entering from above, have full sun exposure, and not be situated over a busy roadway passing underneath the structure.
b) To function as a night roost, bridges constructed from pre-stressed concrete girder spans, cast in place spans, or steel I-beams are best. Bats alo prefer vertical concrete surfaces located between beams that provide protection from wind and remain warm at night.

10. Develop wildlife-friendly maintenance practices, such as lead paint recovery and timing of operations

11. Conduct monitoring of wildlife use of new and retrofitted structures (e.g., remotely-triggered cameras, track beds) to assess effectiveness of mitigation measures for the purpose of making appropriate adjustments as needed and improving designs of future mitigation measures

Small Box or Pipe Culverts

A) CREATE OR MAINTAIN FUNCTIONAL WILDLIFE CROSSINGS AT AN AVERAGE INTERVAL OF 1/4 MILE OR LESS ALONG THE I-70 MOUNTAIN CORRIDOR TO PROVIDE PASSAGES FOR SMALL MAMMALS. TO ACCOMPLISH THIS:

1. Where a drainage structure (culvert, concrete box culverts (CBC) or bridge) is needed as part of the highway system, install, modify or maintain existing drainage structures to accommodate wildlife movement.

Where terrain permits and where it is practical:

a) Replace small drainage culverts with culverts of no less than 3' diameter for small-bodied animals or 4' for medium-bodied animals (e.g., coyotes and bobcats), unless terrain does not permit. When installing equalizer pipes between wetlands with small mammal ramps, pipes must be minimum 4' diameter.
b) Install concrete pipes rather than corrugated steel, as the concrete provides a better surface for wildlife movement and absorbs some moisture, which can facilitate movement for some species.
c) Consider installing a low-gradient dry culvert for wildlife passage adjacent to a steep gradient drainage culvert.
d) Culverts should be built or modified with dry ledges for use by water-shy organisms; these ledges should be constructed to be able to withstand flood events.
e) Routine maintenance of culverts is essential to maintain culvert functionality for wildlife movement to remove accumulated sediment or other obstructions inside the culvert or at the culvert entrances.
f) Maintain natural vegetation cover, including low-stature cover for amphibians.
g) Avoid using rip-rap or boulders to maintain aprons at the culvert entrances as these may be difficult for some small animals to negotiate. If a rip-rap apron must be used, consider placing topsoil over the rip-rap along the edges so as to create a natural path or game trail.
h) Integrate fencing and structures to guide animals to crossing structures. Fencing at small culverts used by medium-bodied animals (e.g., coyotes and bobcats) should be 3-6' high, while fencing for small-bodied animals should be at least 3' high with a small mesh size and entrenched into the ground several inches to prevent animals from digging under. For reptiles and amphibians, a fine mesh fence, concrete walls, or aluminum flashing may be used. Remove and maintain trees, brush, etc that could allow an animal to climb over the fence.
i) Construct and/or reposition wildlife fencing such that all culvert outlets are located outside of the ROW.

2. Enhance existing and new structures with the installation of small mammal ramps or rock walkways that extend the length of a culvert so that small mammals can cross even in wet conditions. Small mammal ramps in culverts are particularly recommended where the roadway bisects a wetland or riparian zone [3]

3. Where possible, use cable median and shoulder barriers instead of jersey-style walls. Where concrete median or shoulder barriers are required, install jersey barriers with 'scuppers' or small openings on the bottom, or barriers with intermittent gaps to allow small mammals to pass through (note: the effectiveness of such gaps has not yet been proven or disproven).

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[3] For small mammal ramp guidelines, refer to:
Montana Department of Transportation Small Mammal Ramp Guidelines.

II. CONSIDERATIONS FOR FISH PASSAGE

A) MAINTAIN OR RESTORE STRUCTURAL AND FUNCTIONAL CONNECTIVITY FOR FISH SPECIES (BOTH ADULTS AND JUVENILES) AT ALL ROAD-STREAM CROSSINGS. TO ACCOMPLISH THIS:

1. Design new structures at road-stream crossings to facilitate fish passage

Where practical:

a) Retain, restore or mimic the existing physical and morphological conditions in the stream and floodplain to the greatest extent possible. Use stream simulation techniques and appropriate reference reaches to guide the design and construction of new or replacement structures, with the aim of creating conditions inside the structure as similar as possible to the stream channel in both structure and function (refer to: http://stream.fs.fed.us/fishxing/aop_pdfs.html)
b) Replace a culvert with an oversized arch culvert, 3-sided box culvert, open-bottomed pipe culvert, or entrenched pipe culvert that is wide enough to prevent channel constriction by accommodating the full channel width and allow for design flows (i.e., natural substrate through culvert, bottom surface of structure should be flush with grade, no drop-offs or plunge pools, and minimize turbulence and channel constriction).
c) A bridge overpass alignment should encompass the natural floodplain, including meanders and riparian banks, and allow for minimal use of bank armoring strategies such as riprap or concrete wall bridge supports.
d) Minimize culvert length to the greatest extent possible within the natural course of the stream. Where a stream crosses an extended highway footprint and associated infrastructure (e.g., highway on/off ramps, frontage roads, adjacent developed areas), install multiple shorter culverts rather than one long culvert.
e) Minimize the degree of forced changes in flow direction, by installing a wider structure that accommodates a natural stream meander as it passes under the road or by installing a curved culvert to better preserve inlet and outlet channel alignments and to prevent bank scour, undercutting or structural failure.
f) Design culverts such that water velocity, depth and grade through the structure is consistent with upstream and downstream channel conditions.
g) Design passages with consideration of the impacts of both high and low flows on fish passage. Design velocity criteria to provide passage for the weakest swimming individual (e.g., juveniles) during a range of flow conditions.
h) Provide low-flow channels in culverts where needed by installing the invert of the culvert below the grade of the natural substrate of the stream to ensure that a minimum water depth can be preserved through the culvert as flow levels fluctuate (e.g., in streams where flow depth may seasonally drop below the minimum depth required for fish passage).

i) Decrease maximum flow velocity through a culvert as culvert length increases and provide rest areas for fish moving through the culvert.
j) Daylight long culverts as much as practically possible while providing best management practices and natural riparian vegetation for controlling for the inflow sediment and runoff from the roadway.
k) Plant and maintain native riparian vegetation at the inlets and outlets of all crossings.
l) Maintain road sand traps to prevent the siltation and pollution of streams and provide regular maintenance to prevent sediment build-up or debris accumulation at culverts.
m) Construct wetlands along the highway right-of-way wherever practical to reduce nonpoint source pollution into receiving streams and funnel roadway sediment and runoff to sediment traps or vegetated buffer areas away from stream channels.
n) Install flared end sections on culverts to reduce erosion at the inlets and outlets of water conveyance structures.

2. Retrofit existing culverts that are not due for immediate replacement to facilitate fish passage.

a) Install securely anchored baffles (corner or side) or rock weirs and provide streambed substrate inside the culvert to add roughness, reduce flow velocity, increase flow depth through the culvert, and create pools that can act as resting areas for fish moving through the culvert where flow criteria allows for reduced culvert capacity. Design baffle heights and profiles with consideration for high and low flows.
b) Install weirs to concentrate low flows into multiple pools with narrower, deeper channels where needed to ensure that a minimum water depth can be preserved through the culvert as flow levels fluctuate (e.g., in streams where flow depth may seasonally drop below the minimum depth required for fish passage). Use tailwater control weirs outside of the culvert barrel to increase flow depths in the culvert during periods of low flow.
c) Use rocks in culverts to simulate the grade-stabilizing functions of embedded debris.
d) Improve transitions at culvert inlets and outlets to accommodate for forced changes in flow direction due to skewed culverts.
e) Balance control measures by installing flared end sections or control weirs for slowing flow velocities and excessive turbulence at culvert inlets
f) Repair perched outfalls by constructing step/pool structures with natural materials to allow for aquatic connectivity. Provide a sufficient pool depth at outlets where fish have to jump to enter a culvert. Design jump height for specific species of concern.
g) Maintain culvert improvements to prevent them from becoming clogged with sediment or debris.
h) Plant and maintain native riparian vegetation at the inlets and outlets of all crossings.

3. Integrate aquatic and terrestrial connectivity goals at all road-stream crossings as appropriate (e.g., include dry pathways for terrestrial species, as needed)

a) Oversize crossing structures to accommodate both aquatic and terrestrial species.
b) Install multiple crossings at varying invert elevations that can perform as dry crossings for terrestrial species and low flow crossings for aquatic species while improving the morphological characteristics of the floodplain and allowing for increased flow capacity during high runoff events. Note that multiple structures at one site may have higher maintenance demands than a single larger structure, and the main crossing structure must be large enough to accommodate flows, sediment and debris.

4. Coordinate with the Colorado Division of Wildlife

a) Aquatic connectivity is not always desirable. Install or maintain aquatic barriers where needed to control the spread of invasive species or disease and/or to protect pure populations of native species. Likewise, remove barriers that no longer serve their intended purpose.
b) Obtain information on the types of species occupying specific streams and design the range of flow velocities, water depth and other attributes for those specific species and life stages. Where such information is lacking, unless there is an explicit need for an aquatic barrier, design road-stream crossings to facilitate fish and aquatic organism passage.
c) To determine the most cost-effective use of funds for constructing new structures or retrofitting existing structures, consider the road-stream crossing relative to the entire stream network, including how it relates to other road-stream crossings or barriers.

5. Minimize impacts to aquatic species during construction

a) Concentrate construction activities during periods of low flow to avoid critical time periods such as fish migration and spawning seasons, and to minimize direct impacts to wildlife and their habitat.
b) Minimize disturbance to the length of the natural stream channel and natural flow of water as well as to the riparian banks and vegetation, and restore areas that have been disturbed using local materials and seed.
c) Clean all equipment and gear before and after they are exposed to the stream to prevent the transmission of aquatic nuisance species or aquatic diseases into or out of the drainage.
d) Remove temporary fills and structures once construction is complete.
e) Install and maintain all best management structures to reduce sedimentation into a stream during construction and remove all temporary BMP's once natural vegetation has been re-established.

APPENDIX G: ALIVE Committee Members (2011)

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