I-70 West Vail Pass Habitat Linkage
Structure Location, Design Criteria, and Conceptual Design Report

Colorado Department of Transportation Region 3



December 2009

HABITAT LINKAGE

FELSBURG
HOLT &
ULLEVIG

West Vail Pass

Structure Location and Conceptual Design Report
Region 3

Prepared by:
Felsburg Holt & Ullevig

Prepared for:
Colorado Department of Transportation
Region 3 – Eagle Residency
714 Grand Ave
PO Box 298
Eagle, CO 81631

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

In 2005, the Colorado Department of Transportation (CDOT) received a federal grant from the Public Lands Discretionary Funds to analyze the feasibility of a vegetated wildlife overpass over Interstate 70 (I-70) on the west side of Vail Pass. This project is independent of the I-70 Mountain Programmatic Environmental Impact Statement (PEIS). The federal grant is being used to identify an appropriate location for a wildlife overpass within the project area, develop design criteria, and proceed through the design process, as much as possible. This report, however only presents information completed through the first of two task orders for the project. The first task order, and thus this report, concludes with the conceptual design of the overpass structure. The second task order will be utilized to develop as much of a set of preliminary design plans as possible.

The overall purpose of this project is to understand wildlife movement patterns and associated wildlife/ vehicle conflicts in order to improve habitat connectivity on West Vail Pass, which is a key component to habitat connectivity in the central Colorado mountainous area. This is accomplished by locating, sizing, and detailing an appropriate structure that provides a suitable wildlife movement opportunity. Locating wildlife mitigation structures is typically accomplished through the use of previously conducted wildlife monitoring studies, animal vehicle collision data, and the knowledge of local experts.

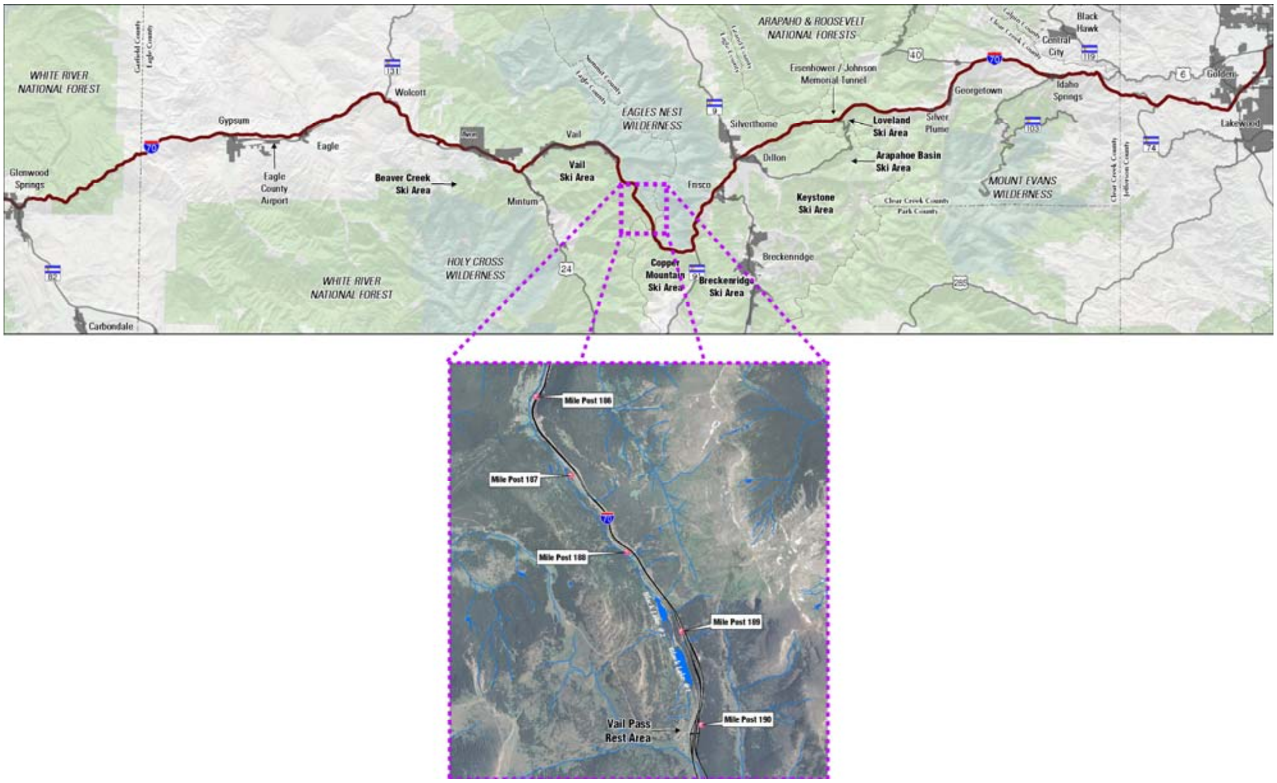
This document discusses the background, methodology, and results of the process used to identify the specific location for the vegetated wildlife overpass in the Study Area. It also presents the conceptual design of the structure.

2.0 BACKGROUND

2.1 WEST VAIL PASS STUDY AREA

The Study Area includes I-70 along West Vail Pass between milepost 185 and 190 in Eagle County, Colorado. Vegetation within the Study Area is consistent with the Subalpine Life Zone (greater than 9,000 feet to approximately 11,400 feet) and is dominated by coniferous forest, meadows, riparian forests, and shrubs. A variety of wildlife species are associated with and rely on these vegetative communities and include: elk, black bear, American marten, porcupine, yellow-bellied marmot, snowshoe hare, and pine squirrel (PEIS, 2004). USDA Forest Service land lies on both sides of the interstate on West Vail Pass. Natural habitat is often very close to the roadway on the pass. There is a general downslope trending to the south towards Black Gore Creek.

I-70 on the west side of Vail Pass has two distinct areas in relation to the ability of wildlife to move across the roadway. The lower portion of the pass (approximately from milepost 181.7 through 186) has a series of bridge structures over drainages and rivers. This area allows for wildlife movement across the highway without the need for animals to traverse over the roadway.



The upper portion of the pass (approximately 186 through 190) does not have any structures that allow for free flow wildlife movement. For animals to cross the interstate in the upper portion of the pass, they must traverse across the travel lanes. Additionally, there are multiple barriers along the roadway that wildlife must negotiate (i.e., guardrails, median barriers, and grade separation of the east and west bound lanes of I-70).

2.2 FOREST SERVICE LANDSCAPE LINKAGE MANAGEMENT UNITS

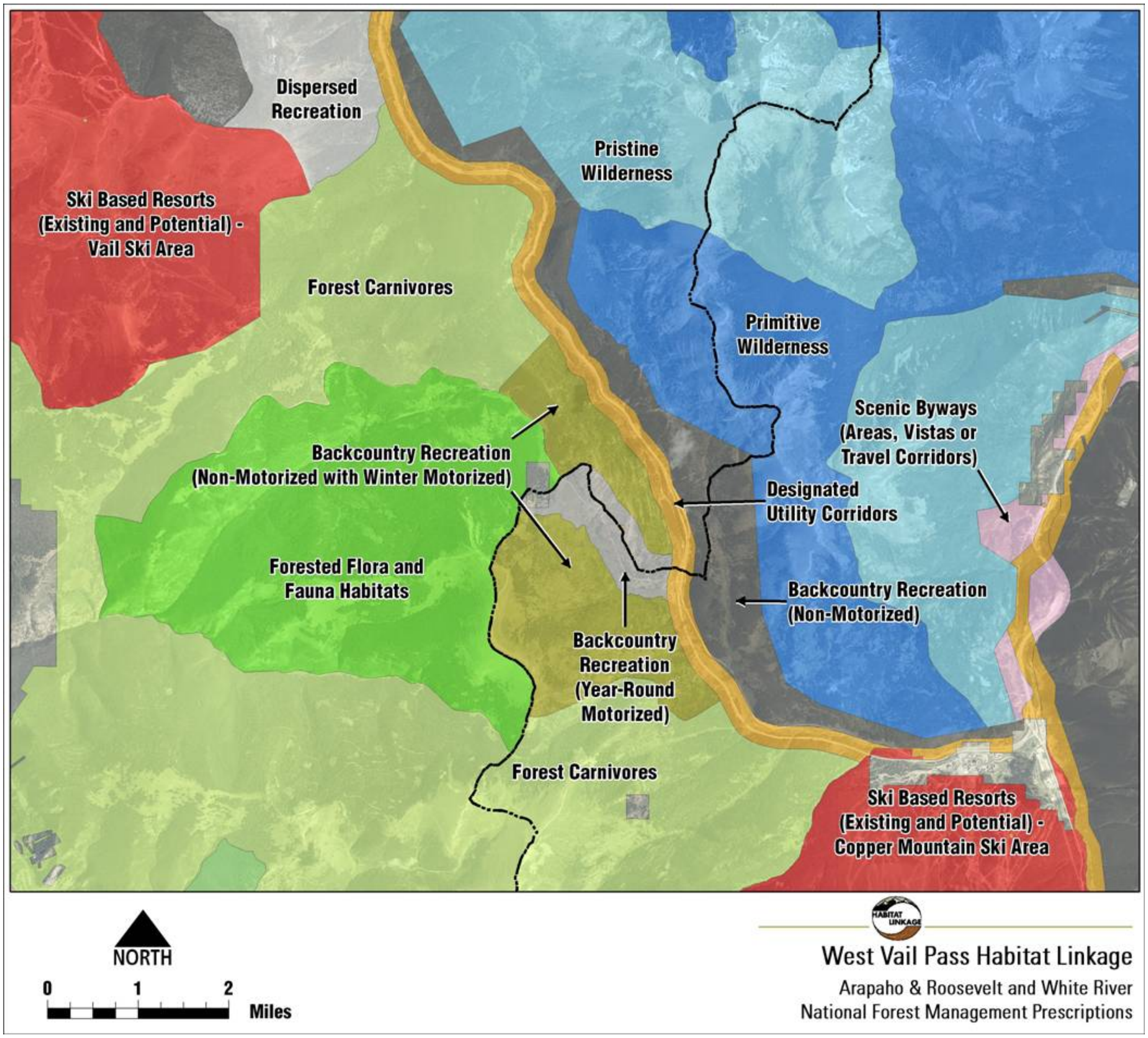
The USDA Forest Service manages a portion of the study area as a forested landscape linkage management unit (see **Figure 1**). The resource management goals within these zones are intended to be consistent with the needs of species that utilize forested cover habitat and to improve wildlife movement between the designated wilderness areas.

The USDA Forest Service also manages the lands south of I-70 within the West Vail Pass study area for both motorized and non-motorized recreation. Motorized winter recreation is allowed south of I-70, near the top of the pass (see **Figure 1**). Recreational parking is also available at the top of the pass. This area is managed for non-motorized recreation and winter motorized recreation between milepost 187 and 190. The area north of I-70 is managed for non-motorized recreation for the entire length of the Project Area.

2.3 I-70 PEIS

CDOT and Federal Highway Administration (FHWA) are preparing a PEIS for the I-70 Mountain Corridor to evaluate transportation alternatives between C-470 near Golden and Glenwood Spring. This project includes approximately 144 miles of highway. A draft version of the PEIS was released in 2004. The I-70 corridor bisects many historically-important movement routes for wildlife species, including ungulate species such as mule deer and elk.

Figure 1 USDA Forest Service Management Units



As part of the PEIS, an analysis was conducted of the potential impacts of the existing highway system on wildlife habitat and movement within the mountain corridor and potential mitigation strategies to help improve wildlife movement and facilitate increased driver safety by reducing the potential for animal-vehicle collisions (AVCs). CDOT and FHWA developed a working group to specifically address wildlife movement issues throughout the corridor. This group, the ALIVE (A Landscape Level of Integrated Valued Ecosystems) committee, consisted of representatives from the United States Department of Agriculture Forest Service (Arapaho-Roosevelt National Forest and White River National Forest), CDOT, Colorado Division of Wildlife (CDOW), FHWA, Bureau of Land Management (BLM), and the United States Fish and Wildlife Service (USFWS).

The ALIVE committee identified important areas (designated as Linkage Interference Zones [LIZ]) for wildlife movement throughout the corridor. The LIZ locations were determined by integrating local expert knowledge concerning wildlife within the corridor, habitat characteristics, and a GIS analysis of potential roadway barriers (e.g., retaining walls, jersey barriers). Through this process, the upper and lower portions of West Vail Pass were identified as a LIZ. The Project Area is surrounded by the White River National Forest and has been designated as a lynx linkage area, indicating that suitable habitat exists for lynx activity. A portion of the area surrounding West Vail Pass is managed as a forested landscape linkage, and is intended to serve as a connection between the Eagle's Nest Wilderness and the Holy Cross Wilderness areas. The land management (i.e., National Forest Lands) of the surrounding area provides an opportunity to conserve wildlife habitat.

Wildlife crossing structures were recommended for West Vail Pass at mile markers 188.0 and 186.3, with game fencing between the proposed structures. However, the sizes and types of mitigation structures (i.e., overpass or underpass) were not identified.

3.0 DATA COLLECTION

This section describes the methodology and the results of the data collection efforts for the West Vail Pass Habitat Linkage Assessment. The focus of this effort has been on collecting data and information regarding wildlife activity, habitat, and movements within the study area (milepost 185 to 190). The collection of data was intended to aid in identifying a location of a vegetated wildlife overpass within this area.

This section presents the data quality objectives, information search process, and a summary of the information used to identify a specific structure location.

3.1 DATA QUALITY OBJECTIVES

Identifying key components of the data to be collected provides a more focused and beneficial process. It can help to eliminate extraneous information that does not lead to the specific goal, in this case, identifying a specific structure location. To this end, the Project Team used two different types of information. The first included previously published reports that identified Vail Pass as an important linkage area, and the second included data specific to the stretch of I-70 within our study area, from milepost 185-190.

This type of information was determined to be pertinent for identifying the specific location of the structure in the Project Area. Focusing on this information (i.e., specific to West Vail Pass) allows the Project Team a more precise understanding of wildlife movement in the Project Area. Information not specific to the Project Area, while important, does not add in narrowing down an exact location for the overpass structure.

3.2 DATA GATHERING APPROACH

The Project Team used a combined approach to select the location of the wildlife overpass structure that included:

1) Existing research on wildlife movement and habitat in the project area

2) Geographic Information System (GIS) Analysis

3) Input from an expert-based wildlife panel

This information was used in determining the target species, identifying a specific location for the structure, and design criteria appropriate for those species. Engineering constraints and feasibility were also considered to assist with identifying the structure location.

Many different types of information regarding wildlife movement are available. Based upon previously conducted studies in the State of Washington and in Colorado, the following types of information are useful in determining the location of a wildlife crossing structure:

- Motion-activated photographs
- Wildlife track data in summer and winter
- Radio-telemetry tracking individual animal movements

- Animal-vehicle collision information
- GIS-based habitat/landscape information (including surrounding land uses)

Equally important to the location of a wildlife structure is the professional opinion of local wildlife experts from land management agencies. These individuals often have a significant amount of information regarding wildlife usage of areas that may not be documented in reports or databases.

4.0 SUMMARY OF COLLECTED INFORMATION

This section provides a summary of the information collected that was used to help identify the location for a wildlife overpass mitigation structure on West Vail Pass. The Project Team utilized a literature search, GIS information, engineering considerations, input from a Wildlife Panel, and photographic database to determine the appropriate location of the wildlife overpass structure.

4.1 LITERATURE SEARCH

The Project Team performed a literature search to identify previously conducted wildlife studies on West Vail Pass. The information summarized below is from published or readily available wildlife information specific to West Vail Pass. Some studies had research specific to West Vail Pass, while others simply considered West Vail Pass in an overall context.

4.1.1 Linking Colorado's Landscapes-A Statewide Assessment of Wildlife Linkages Phase I Report

The Southern Rockies Ecosystem Project (SREP), in collaboration with the US Department of Transportation, CDOT, Colorado State University, and the Nature Conservancy conducted a broad-level assessment of wildlife movement linkage areas that provide landscape-scale connectivity within Colorado for multiple species (SREP, 2005). The linkage areas were derived from a series of expert workshops conducted in April and May 2004. Additionally, a least-cost path modeling linkage analysis was also completed for Canada lynx, Gray wolf, Pronghorn, and aquatic systems.

Wildlife linkage areas were prioritized with the goal of conducting further analysis of the highest priority areas. This additional analysis would involve refining the spatial extent of the linkage areas and then focusing immediate conservation and mitigation actions at these defined locations. Prioritization was based primarily on conservation priority, ecological functionality, degree of future threat, and conservation opportunity. Consideration was also given to animal-vehicle collision rates, opportunities to coordinate mitigation efforts with planned transportation projects, and the presence of local partners to support mitigation efforts.

As part of the expert workshops, Vail Pass was identified as one of 176 landscape-level linkages throughout Colorado. Vail Pass was also selected as one of the 23 priority linkages requiring additional finer-scale analysis. This linkage was identified specifically for Canada lynx and was one of three high priority north-south lynx linkages in the Colorado Central Mountains. The other high priority north-south lynx linkages in the Colorado Central Mountains included Berthoud Pass and Laskey Gulch. Identified threats to the functionality of the Vail Pass linkage were attributed to resort development, high recreational use, and traffic volume.

Vail Pass was not identified as one of the top 50 lynx linkages through the modeling effort; however, the presence of I-70 as a barrier affecting existing ecological functionality can influence the modeling results and should not discount the importance of this linkage area for a range of species.

4.1.2 Identifying the Best Locations Along Highways to Provide Safe Crossing Opportunities for Wildlife

This CDOT-funded project included an assessment of mid-and large-sized mammal activity (e.g., mule deer, elk, coyote) along two highway study sites (Barnum, 2003). One of the study sites was along a stretch of I-70 from mile post (MP) 183.0 to MP 195.0, which encompasses both East and West Vail Pass, this encompasses the *West Vail Pass Wildlife Habitat Linkage Study Area* (milepost 185.0 – 190.0). Wildlife activity was assessed during the 2000/2001 and 2001/2002 summer and winter seasons.

During the summer seasons, ten roadside transects (200 meters (m) in length) were observed for wildlife tracks in the roadside sand. Track locations were identified in addition to crossing activity. In summary, mule deer were the species most often detected along Vail Pass during the summer months. Other species detected, from highest to lowest number of records, included elk, coyote, mountain lion, and moose.

Several existing underpasses (milepost 183.0, milepost 184.9, milepost 190.8, milepost 191.8) within or adjacent to the study area were also observed for wildlife tracks. Two of the structures are located to the north (milepost 183.0 and milepost 184.9) and two of the structures are located to the south (milepost 190.8, milepost 191.8) of the *West Vail Pass Wildlife Habitat Linkage Study Area*. Track beds were used to identify wildlife activity within/underneath the structures. In summary, mule deer were most often detected using the underpasses. Coyotes, elk, fox, moose, mountain lion, and bear tracks were also observed to a lesser extent at the underpass sites.

During the winter season, “windshield surveys” were performed to observe wildlife activity (i.e., wildlife tracks) within the study area (milepost 183.0 – milepost 195.0). In summary, coyotes were the species most often detected along Vail Pass during the winter months. Other species activity detected, from highest to lowest records, included snowshoe hare, weasel, marten, elk, and red fox.

Several existing underpasses (milepost 183.0, milepost 184.5, milepost 184.9, milepost 190.8, milepost 191.4, milepost 191.8, and milepost 192.5) were also observed for wildlife tracks during the winter months. Three of these structures are north of the *West Vail Pass Wildlife Habitat Linkage Study Area* at milepost 183.0, milepost 184.5, and milepost 184.9 and four of the structures are south of the *West Vail Pass Wildlife Habitat Linkage Study Area* at milepost 190.8, milepost 191.4, milepost 191.8, and milepost 192.5. Coyotes were detected the most often using the underpasses during the winter months. Weasel, marten, hare, and elk activity was also observed at the underpass sites.

Wildlife Activity – At-Grade Crossings

The project also included a spatial pattern analysis to assess the large-scale (landscape) and small-scale (roadside) patterns of wildlife activity.

Landscape-Scale Patterns

Species were more likely to cross I-70 at-grade during the winter months when compared to crossing activity during the summer months. During the winter months, activity (75% of total tracks) was clustered within 2.5 miles of Copper Mountain Resort (milepost 192.5 – 195). During the summer months, there were less than 50 percent as many tracks recorded along the west side of Vail Pass (183 – 190) than the east side of Vail Pass (190 – 195). The difference in activity was attributed to different highway design features and landscape characteristics.

Landscape features that were correlated with high crossing activity (i.e., areas most often crossed) included:

1) Presence of habitat on both sides of the road,

2) Presence of linear guideways (e.g. drainages, ridgelines, fence lines), and

3) Slope steepness (i.e., moderate slope) and complexity (i.e., less rugged).

Other landscape-scale influences included the number of and quality of underpasses, configuration of underpasses, and landform orientation (e.g., ridgelines, drainages).

- Wildlife crossing activity at-grade was higher in areas that had a smaller length of underpass per length of highway.
- During the summer months along West Vail Pass, the alignment of the eastbound and westbound bridge structures make it preferable for wildlife to cross underneath I-70 and less preferable to cross at-grade. This conclusion was similar during the winter months for the non-Copper Mountain Resort area (milepost 183.0 – 192.5).
- Major ridgelines and drainages along West Vail Pass primarily run parallel to I-70. Wildlife species that are influenced by these features would not approach and cross I-70 as commonly as wildlife species that don't use these features as movement conduits. During the winter months, this relationship is less distinguished and movement may be more influenced by snow depths within the West Vail Pass Wildlife Habitat Linkage Study Area, rather than the landscape features mentioned above.

Local-Scale Patterns

At the local-scale, "crossing zones" (i.e., highway segments with highest probability of crossing activity) were associated with surrounding landscape and roadway features. During the summer months, eight "crossing zones" were identified on West Vail Pass between MP 187 and 188.

During the winter months in the non-Copper Mountain Resort Area (MP 183.0 – 192.5), which encompasses the *West Vail Pass Wildlife Habitat Linkage Study Area*, fourteen "crossing zones" were identified (5– westbound and 9– eastbound).

The results of the study suggested that roadway features, such as jersey barriers, guardrails, and retaining walls can influence crossing activity, and wildlife may avoid crossing in an area with these features. Landscape features associated with "crossing zones" included distance to cover and the presence of linear guideways. Areas with a smaller distance from the roadside to surrounding vegetative cover were associated with the identified "crossing zones". Also, "crossing zones" were correlated with perpendicular drainages and ridgelines, which both act as conduits for wildlife movement for certain species.

Wildlife Activity at Existing Underpasses

Wildlife activity at existing underpasses was correlated with the structure type and surrounding habitat. All of the structures in the Vail Pass (East and West) study area were span bridges. During the summer months, all of the structures were heavily used by mule deer. Two of the most used structures were on West Vail Pass (MP 183.0, MP 184.9). At these locations, the eastbound and westbound structures are aligned and allow wildlife to pass freely underneath I-70. Additionally, natural habitat exists beneath the structures. Underpass use was much higher during the summer months when compared to the winter months.

4.1.3 Roads and Connectivity in Colorado: Animal-Vehicle Collisions, Wildlife Mitigation Structures, and Lynx-Roadway Interactions (a.k.a. WUMPS) (Draft 2008)

This CDOT-funded study was conducted by Colorado State University researchers and included an assessment of three research areas.

1) An analysis of AVCs hot spot areas was conducted for Interstate, US, and State highways throughout the state and surrounding landscape features associated with the hotspots. The *West Vail Pass Wildlife Habitat Linkage Study Area* does not fall within the top 1 percent or 5 percent of AVCs resulting in fatality and injury or property damage in Colorado from 1986-2004.
2) Wildlife monitoring was conducted at three study sites that encompass areas of planned CDOT construction projects. Pre-construction data was collected and eventually post-construction data will be collected to determine wildlife mitigation structure efficacy. These study sites are not located near the *West Vail Pass Wildlife Habitat Linkage Study Area.*

3) Lynx activity was monitored at seven underpass structures located within four study sites (Muddy Pass Safety Improvement Project, Berthoud Pass East Improvement Project, SH 9 North of Silverthorne Improvement Project, Wolf Creek Pass Project). These study sites are not located near the *West Vail Pass Wildlife Habitat Linkage Study Area.*

In addition, lynx tracking data was analyzed using GIS to identify lynx distribution and movement in relation to roads and potential areas where lynx may be more likely to cross highways throughout Colorado. The analysis revealed that Vail Pass is an area with lynx activity and a “moderate” potential for movement across I-70.

4.2 GIS DATA ANALYSIS

The Project Team conducted a GIS-based analyses utilizing available data to aid in the structure location identification. The intent was to develop mapping that might identify a pattern from multiple datasets. The Project Team developed an analysis that normalized data and presents the information in a format that is intended to be quickly and easily understood.

A zonal analysis for characteristics of I-70 in the project area was created using a 0.1 mile increment. The entire project area was divided into 0.1 mile segments and the GIS attributed each of these zones with a piece of information. Based on this information, each zone was color-coated to represent a positive wildlife crossing condition (green) or a negative wildlife crossing condition (red). This same process was repeated for each pertinent dataset. The goal of the zonal analysis was to determine if there was an obvious positive (green-colored) wildlife crossing area along the pass. This would indicate a suitable area for the structure.

The datasets used in the zonal analysis were grouped into two major categories (Physical/Habitat Characteristics and Roadway Characteristics). The datasets developed for each category are presented after each grouping.

- **Physical and Habitat Characteristics** (distance to vegetative cover, slope, visual cues, known crossing areas, presence of drainages perpendicular to Black Gore Creek, and presence of other water features)
- **Roadway Characteristics** (median barriers, guard rails, retaining walls, accident information)

This analysis was developed and prepared for a Wildlife Panel Meeting (A discussion of the Wildlife Panel is presented in **Section 4.4**). The intent was to present the GIS information at the meeting and the larger group would discuss the applicability of the data in assisting in locating the Overpass Structure.

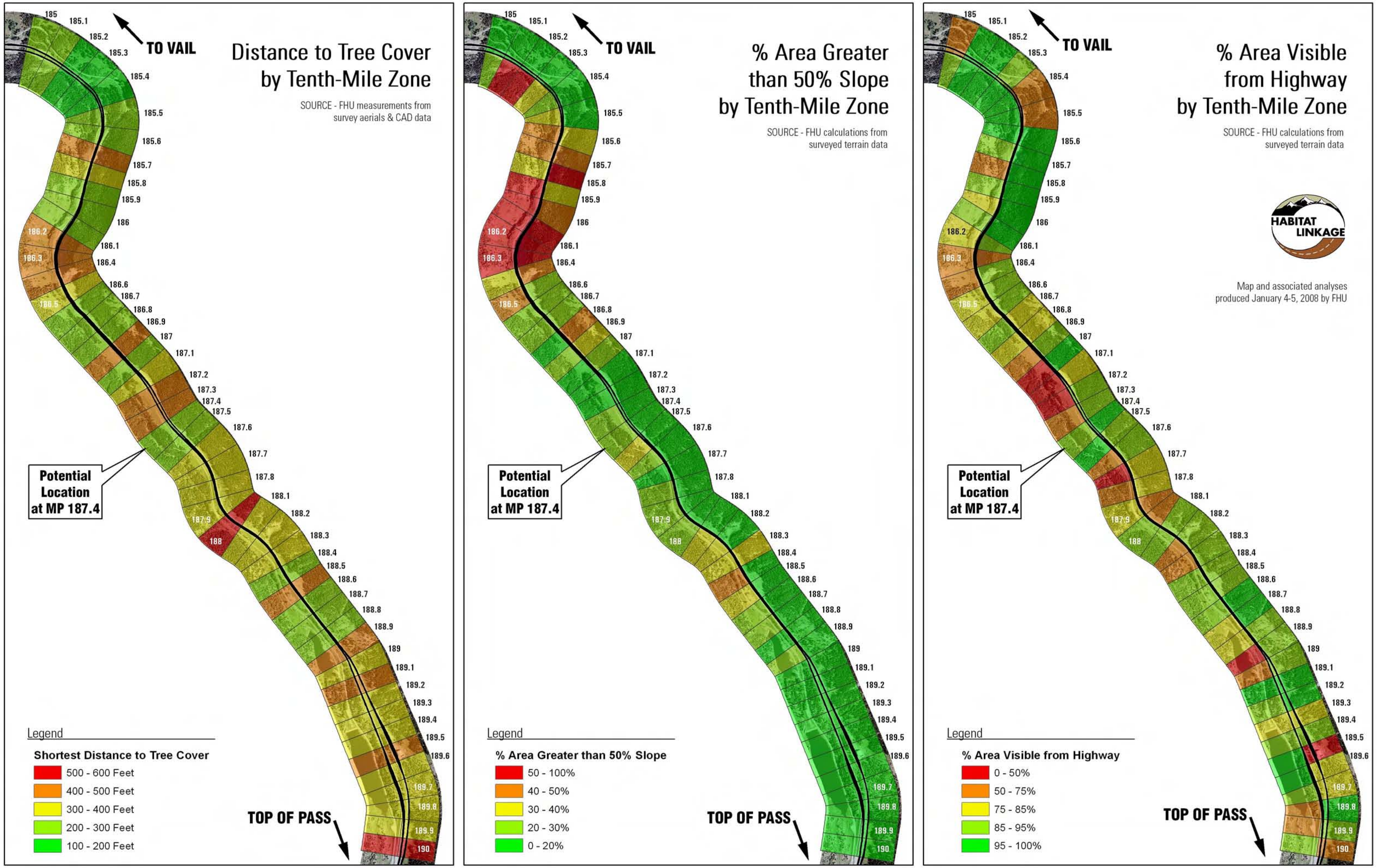
4.2.1 Results of Data Analysis

Figure 2 through **Figure 5** present the results of the GIS zonal analysis and are discussed below. Additionally, information from Barnum (2003) was applied to the same GIS format (**Figure 6**).

Physical and Habitat Characteristics

The intent of considering the Physical and Habitat Characteristics of the project corridor is to identify characteristics of the surrounding area that could be used to estimate areas where wildlife would prefer to cross I-70. These measures were taken from various published documents or knowledge of animal movements. The measures attempted to capture the factors that these documents have identified as being important to wildlife movement.

Figure 2 **Roadside Characteristics**



Distance to Tree Cover by Tenth-Mile Zone

SOURCE - FHU measurements from survey aerials & CAD data

% Area Greater than 50% Slope by Tenth-Mile Zone

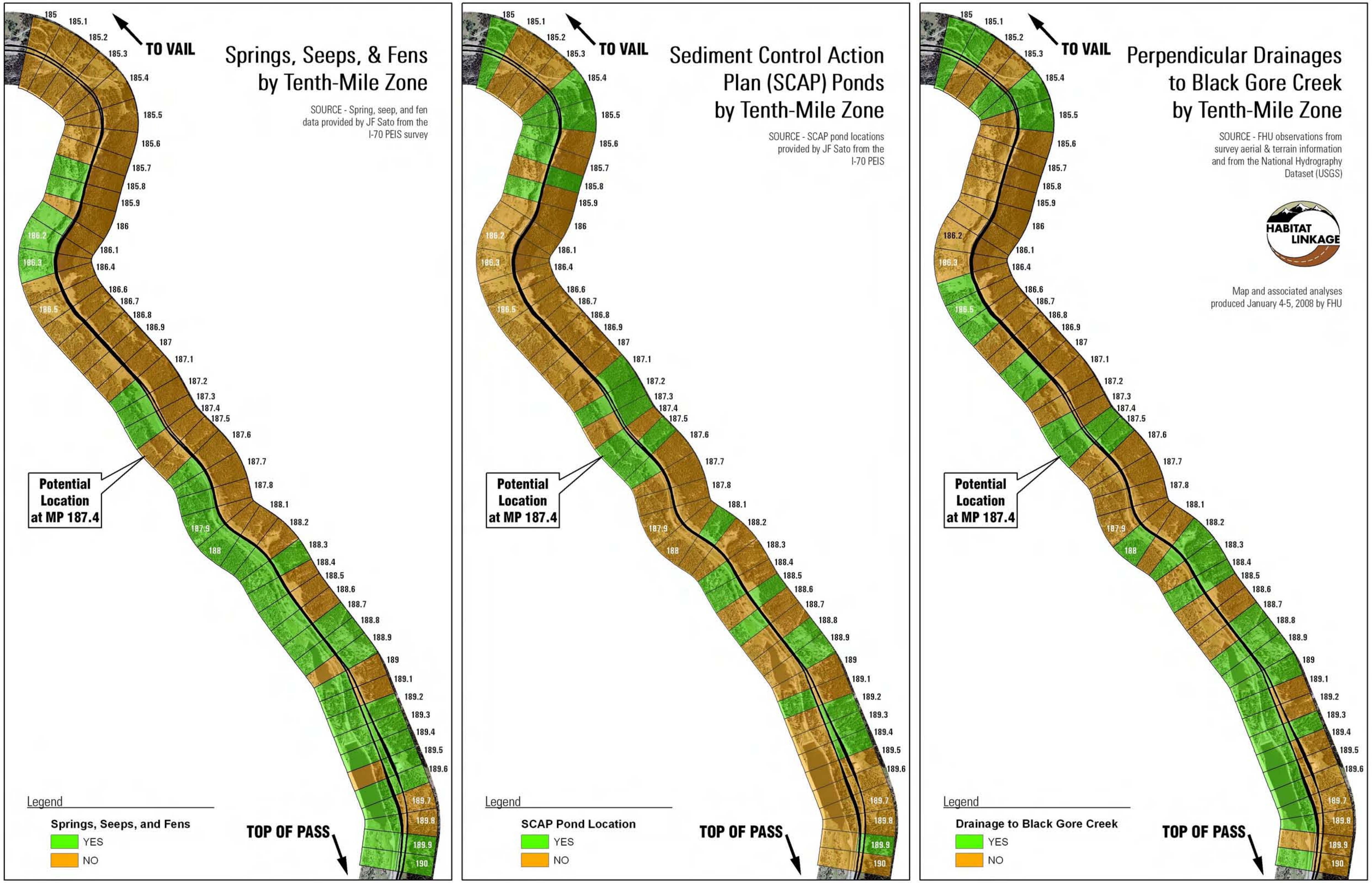
SOURCE - FHU calculations from surveyed terrain data

% Area Visible from Highway by Tenth-Mile Zone

SOURCE - FHU calculations from surveyed terrain data

Map and associated analyses produced January 4-5, 2008 by FHU

Figure 3 Water Features



Springs, Seeps, & Fens by Tenth-Mile Zone

SOURCE - Spring, seep, and fen data provided by JF Sato from the I-70 PEIS survey

Sediment Control Action Plan (SCAP) Ponds by Tenth-Mile Zone

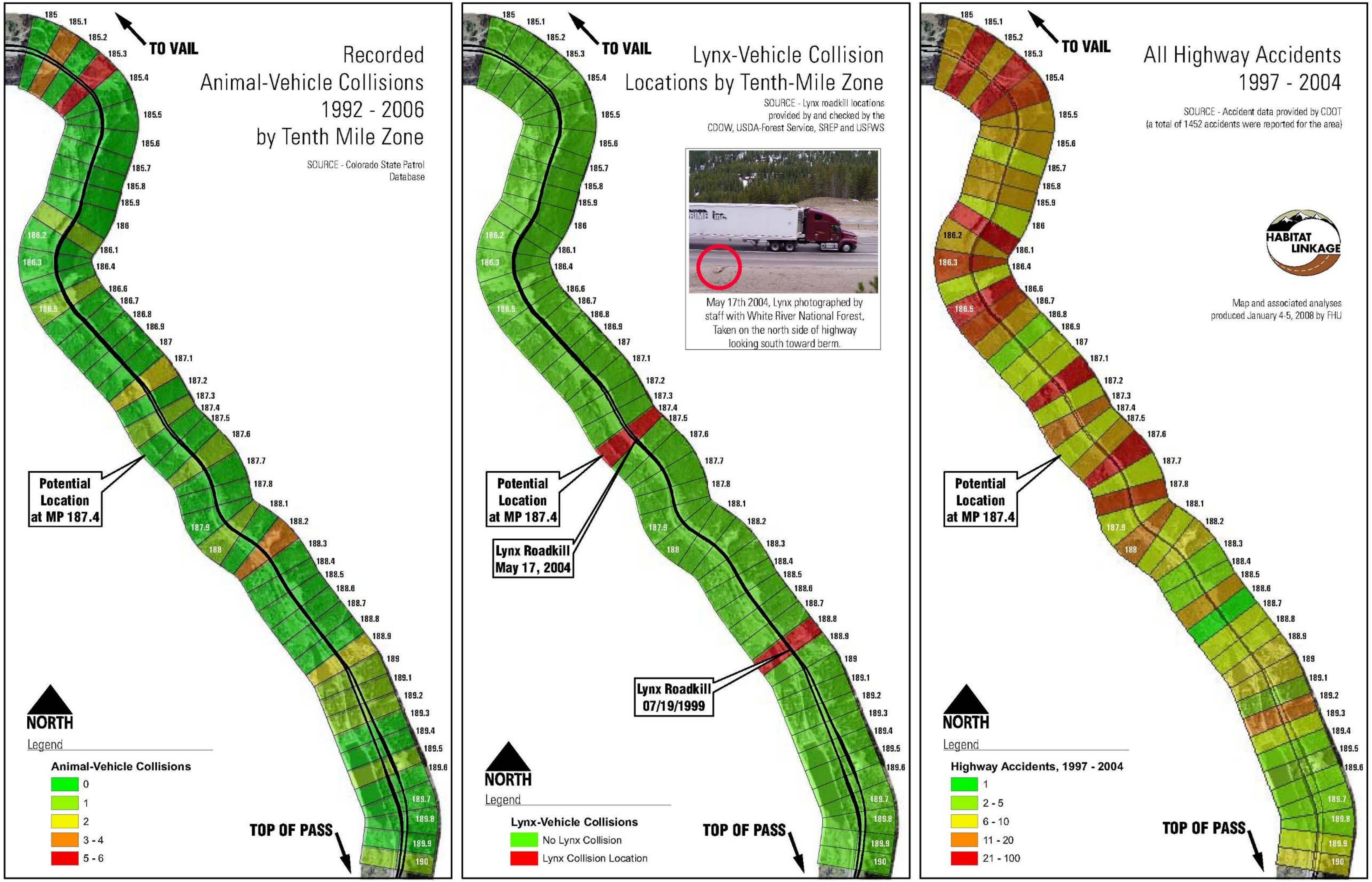
SOURCE - SCAP pond locations provided by JF Sato from the I-70 PEIS

Perpendicular Drainages to Black Gore Creek by Tenth-Mile Zone

SOURCE - FHU observations from survey aerial & terrain information and from the National Hydrography Dataset (USGS)

Map and associated analyses produced January 4-5, 2008 by FHU

Figure 4 Accident Information



Recorded Animal-Vehicle Collisions 1992 - 2006 by Tenth Mile Zone

SOURCE - Colorado State Patrol Database

Lynx-Vehicle Collision Locations by Tenth-Mile Zone

SOURCE - Lynx roadkill locations provided by and checked by the CDOW, USDA-Forest Service, SREP and USFWS

May 17th 2004, Lynx photographed by staff with White River National Forest, Taken on the north side of highway looking south toward berm.

All Highway Accidents 1997 - 2004

SOURCE - Accident data provided by CDOT (a total of 1452 accidents were reported for the area)

Map and associated analyses produced January 4-5, 2008 by FHU

Potential Location at MP 187.4

Lynx Roadkill May 17, 2004

Lynx Roadkill 07/19/1999

Figure 5 Existing Barriers to Wildlife Movement

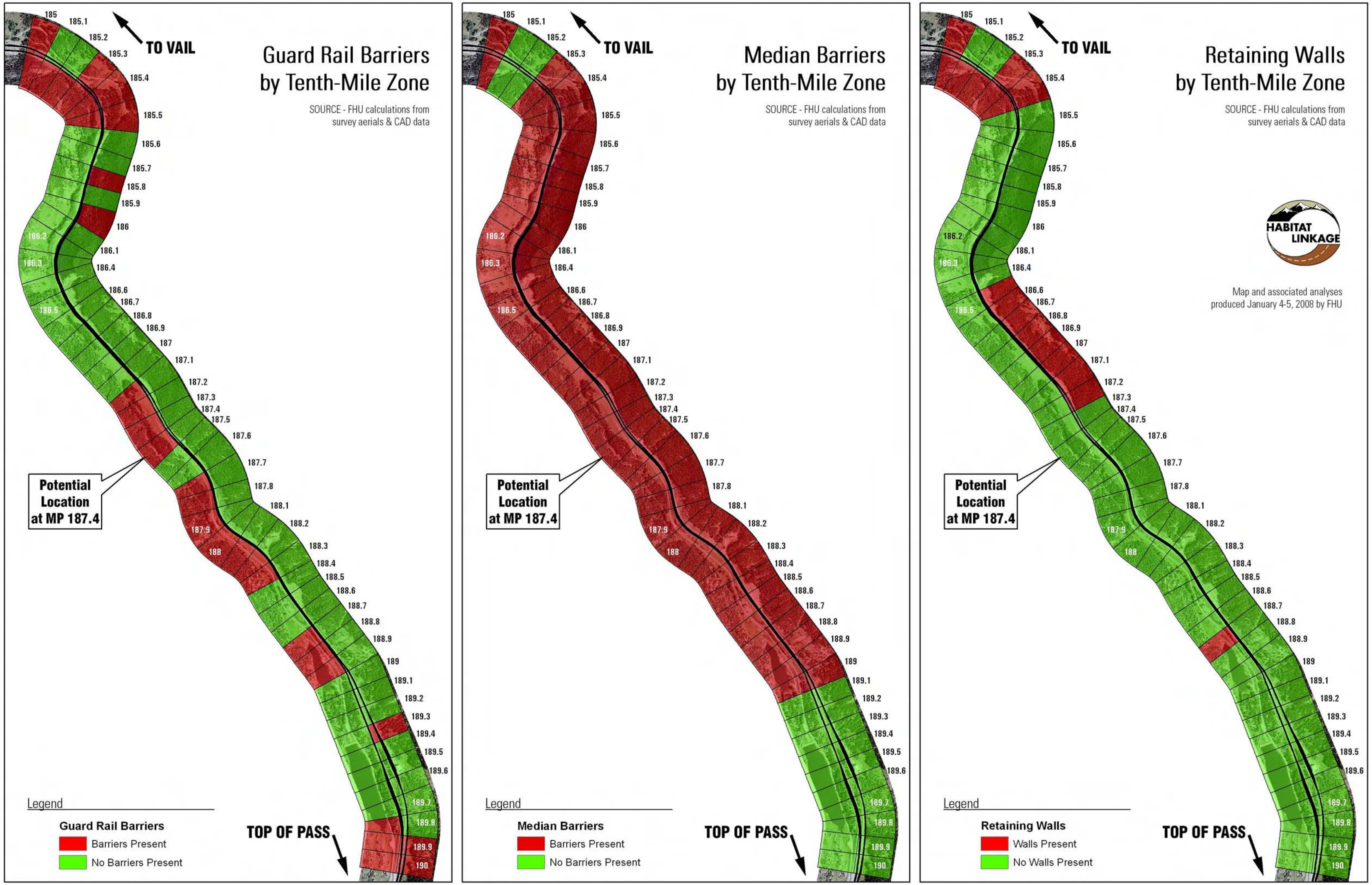
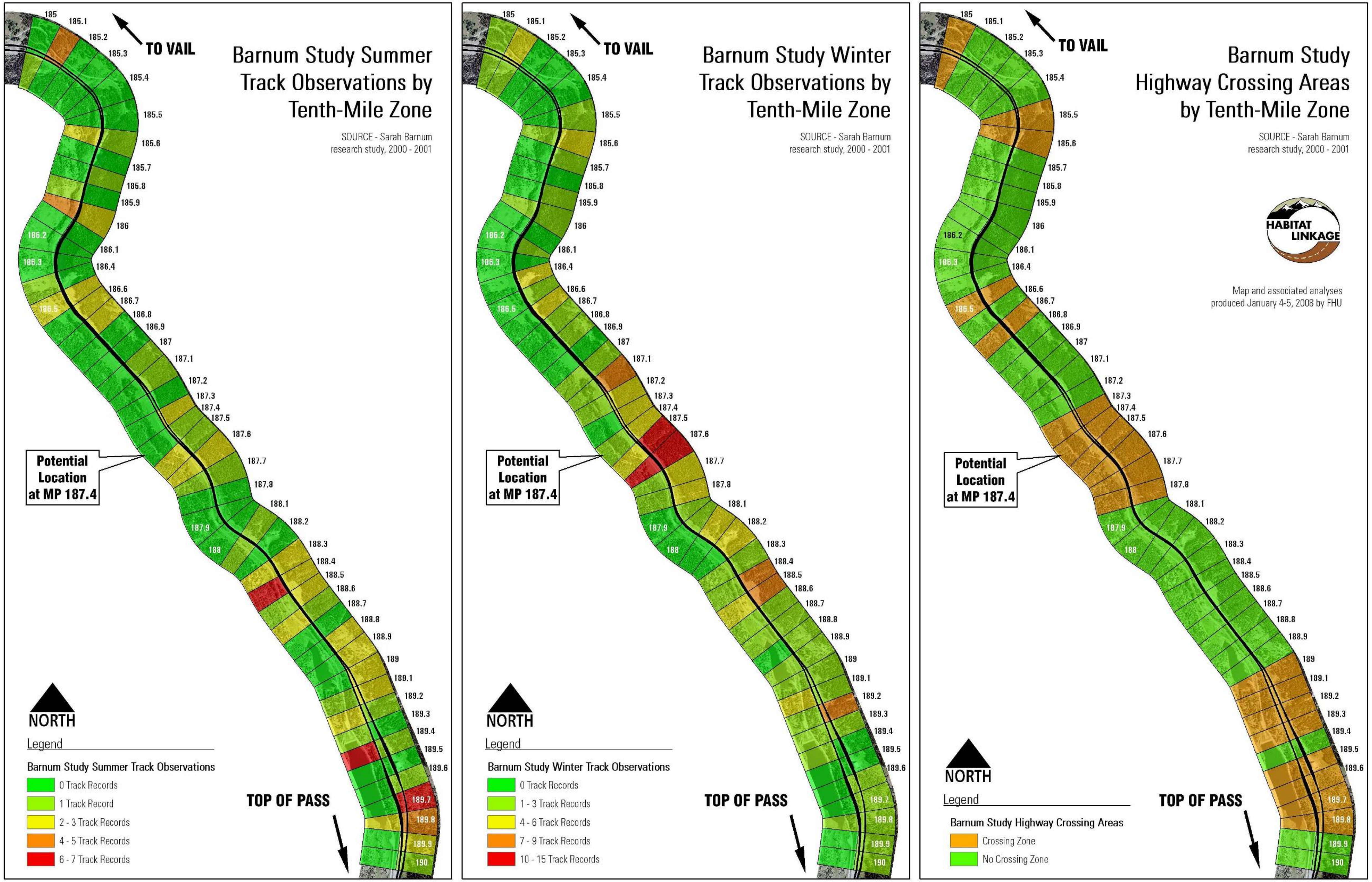


Figure 6 Crossing Areas Identified in Barnum (2003)



The distance to tree cover was determined in Barnum (2003) as being an important measure because it allows for animals to approach the roadway while still remaining in the relative cover of trees. Eight areas, ranging from 0.1 to 0.3 miles in length, had the treeline from 200 to 300 feet from the roadway. One area showed the treeline closer to the roadway, but this area is in the areas of the span bridges where the treeline actually could occur under the structure and thus, not an appropriate area for a wildlife overpass structure.

Considering the slope of the adjacent lands can be an important factor in placing the structure, not just from an engineering standpoint, but also for wildlife. While animals, especially ungulates can traverse very steep areas, a wider range of species may prefer a less steep crossing area. The reason for this is simply that animals will chose to expend less energy crossing a less steep area than a steeper area. This is so the animal can conserve energy for other activities. This type of consideration is consistent with the least-cost path modeling theory. The results of the slope analysis showed that while the project area is relatively steep (sloping from the north to the south), 'flatter' areas occur in the central and eastern portions of the project area. On the eastern end of project area, the slope is very steep where there are steep cliffs on both sides of the roadway.

Information available regarding the wildlife overpass structures in Banff stated that it was important to attempt to establish a sight line from one side of the bridge to the other. This would allow the animals the ability to see suitable habitat from the either side of the structure. The Project Team attempted to measure this by determining how much of the surrounding habitat is visible from the roadway. To interpret this measure, the ideal condition has a green-colored zone on both sides of the roadway. In areas where a red-colored zone on one side of the road means that wildlife cannot easily see the other side of the roadway. The results generally show that about three areas of the project area have suitable visibility across the roadway. There were no large areas of extremely visible areas; conversely, there are a number of areas of very poor visibility.

Barnum (2003) stated that wildlife often travel along waterways to cross roadways and this should be the focus of some wildlife crossings. The analysis looked at drainages that are perpendicular to I-70, as well as the location of sediment control action plan (SCAP) ponds that hold water. These ponds have been known to be an attractant to wildlife along I-70. While there isn't a strong pattern between these two factors, the central portion of the project area does appear to have the largest amount of both these features. This means that this area likely serves as some sort of attractant for wildlife to the roadway and could be a good place to locate the structure.

Barnum (2003), as discussed in **Section 4.1.2,** presents information on the location of wildlife tracks during winter and summer months. The Barnum (2003) report used the track information in GIS to identify crossing zones of focused animal usage. These areas were also used in the GIS analysis.

Another consideration is the presence of seeps and fen weltands. These are very important wetland resources and the US Army Corps of Engineers, who regulates wetland impacts do not typically allow impacting these types of resources. Therefore, not having these in an area is logistically important. There appears to be one area around milepost 187.4 that does not have this resource mapped. Another area has these, but this is where there is the grade-separation of the roadway and does not represent a likely place for a crossing structure.

Roadway Characteristics

Considering the characteristics of the roadway in relation to wildlife movement relies upon identifying those characteristics that impedes wildlife movement (i.e., barriers) and the location of animal-vehicle accidents, as well as overall accidents. These factors can help to understand the project corridor and if the barriers influence wildlife movement by observing an increase AVC at the locations where barriers do not exist. In other words, trying to answer the question, are the animals moving around the barriers and then being struck by vehicles.

Based upon the locations of physical barriers associated with the highway (median barriers, guard rails, and retaining walls), one obvious area exhibited all three of these barriers. This area is where I-70 has a grade-separation of approximately 10 to 12 feet between the westbound and eastbound lanes. However, there did not appear to be a substantial relation to AVCs outside of this area.

Two Canada lynx were struck by vehicles and killed on I-70 in the project area. These two locations occurred at milepost 187.4 and 188.8.

The only obvious pattern of overall accidents in the project area occurred at or near the bends in the roadway, which is to be expected on a roadway on a mountain pass. The intent of this measurement was to determine if the location of the structure would exacerbate an already problematic traffic safety area.

4.3 ENGINEERING CONSIDERATIONS

Engineers from the Project Team evaluated the entire Project Area corridor between mile markers 185 and 190 along I-70 for favorable wildlife overpass locations from an engineering perspective. The most favorable location identified lies near mile marker 187.4, which is approximately at the mid-point of the Project Area corridor.

The topography at this location offers several benefits for construction of an elevated structure over I-70. The north side of the highway appears to be at a favorable grade and elevation for construction of a bridge landing, and other off-bridge landscaping. The elevation difference from the highway to the terrain along the north side of the highway appears to be within a workable range for bridge approach structure. The ground slope on the north side of the roadway is less steep than along a majority of the corridor, which will allow for construction of a fairly simple bridge approach. With the favorable grading at this location, disruption of the existing vegetation along the north side of the highway can be minimized compared to other potential crossing locations.

The south side of the highway at this site has an expansive flat zone that is similar in elevation to the highway. This offers several design advantages, including the allowance for construction of a conventional bridge abutment and off-bridge approaches. A majority of the corridor has severe drop-offs on the south side of the highway that will likely complicate the bridge abutment and approach design, requiring more expensive construction activities. The flat area also provides room for re-aligning an existing bicycle trail in the vicinity. The current trail alignment falls within the area where wildlife would move off the bridge structure and access the creek and wooded areas to the south. The wildlife fencing along the south side of the highway will keep the trail users from accessing the wildlife landing area to the south.

The flat area south of the highway is elevated significantly relative to Black Gore Creek, which parallels I-70. Construction of the wildlife crossing structure at this site should have no impact to the creek. There appears to be sufficient space on the south side of the highway to accommodate drainage.

It is anticipated that some sort or ramp or turnout from the highway will be constructed adjacent to the wildlife crossing structure to allow for maintenance access to the structure. The flat area south of the highway at this location appears to provide a reasonable amount of room for construction of a simple access. Lastly, this site provides for a natural construction staging area, which will be very cost-effective for the contractor and reduce overall site disturbances.

4.4 WILDLIFE PANEL

The Project Team assembled a Wildlife Panel consisting of wildlife specialists from local resource agencies (USDA Forest Service, CDOW, USFWS, and CDOT). Additionally, representatives of SREP and other stakeholders (FHWA and Eagle County) attended and/or participated in this panel. The intent of the Wildlife Panel was to provide insight to assist the Project Team’s decision making process.

A Wildlife Panel Meeting was conducted in Vail, Colorado on January 17th, 2008. A presentation of the collected materials (as previously described) was given followed by a group discussion. The goal of the meeting was to identify if enough information was available to select a suitable location of the structure, determine the target species for the structure, and identify any design characteristics important to consider during design. The materials presented at the Wildlife Meeting are presented in Appendix A. The discussion and recommendations from the Wildlife Panel have been incorporated into the following sections.

The Wildlife Panel identified the following items for the Project Team to consider during the design phase of the project:

- Driver expectancy—a driver should be able to see through the overpass to the other side of the structure. In other words, do not have a structure on a curve such that the driver's sight distance is reduced.
- Shade issues—as it relates to safety by increasing icing effects.
- Areas that minimize conflicts with recreational activities
- Consider the ridgeline to the south as a landscape feature that creates a natural funnel for wildlife movement.
- Consider the I-70 improvements associated with the I-70 PEIS and West Vail Pass Climbing Lanes.

4.5 PHOTOGRAPHIC DATABASE

In 2006, SREP initiated a motion-activated camera program on Vail Pass to aid in the understanding of wildlife usage on Vail Pass in the vicinity of I-70. On West Vail Pass, cameras were arranged in nine (9) transects on both the north side and south side of I-70. The photographs were collected and placed in a database with information about their location, time of day, date, species, and other pertinent information. At the time of the Wildlife Panel meeting, the motion-activated project was ongoing. However, the Project Team utilized the available photographic database to identify a potential location for the overpass structure, as well as species usage along West Vail Pass.

The Project Team's analysis of the available photographs is presented in **Figure 7** through **Figure 9**. A total of 11 wildlife species (not including human or domestic dog) were identified. The highest number of photographs were of mule deer (1,298), followed by elk (299). The high number of human photographs (105) is believed to be the result of the proximity of a hiking trail to the motion-activated camera. **Figure 10** presents the available photographic data in the same zonal GIS format, as previously presented.

Figure 7 **Basic Information from the Photographic Database**

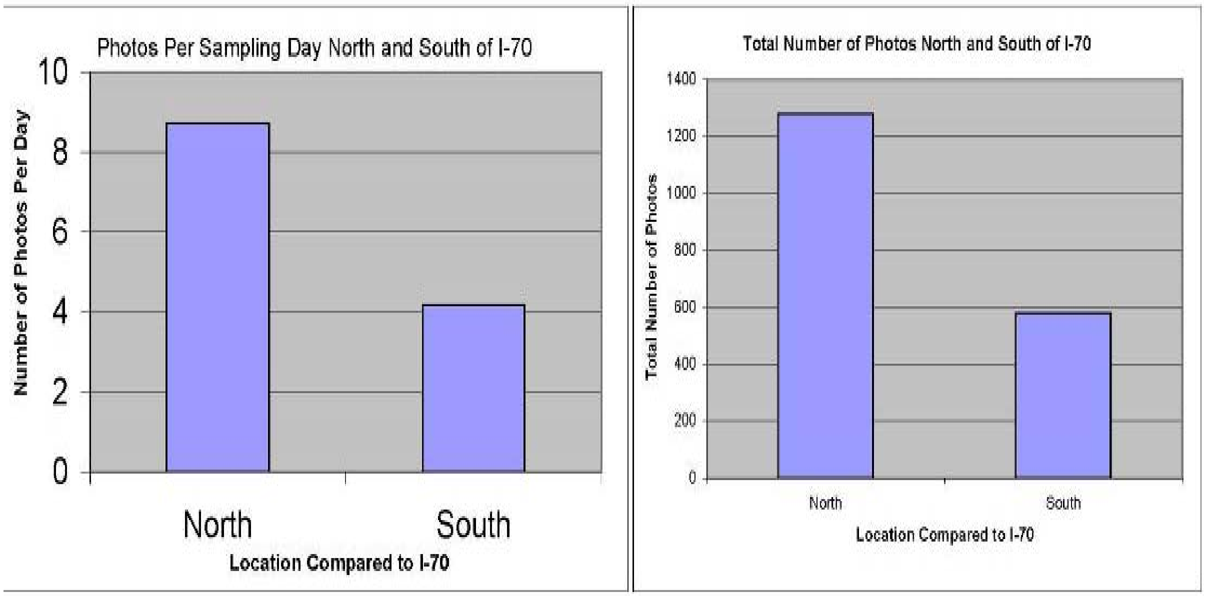


Figure 8 **Species with the Highest Number of Photographs**

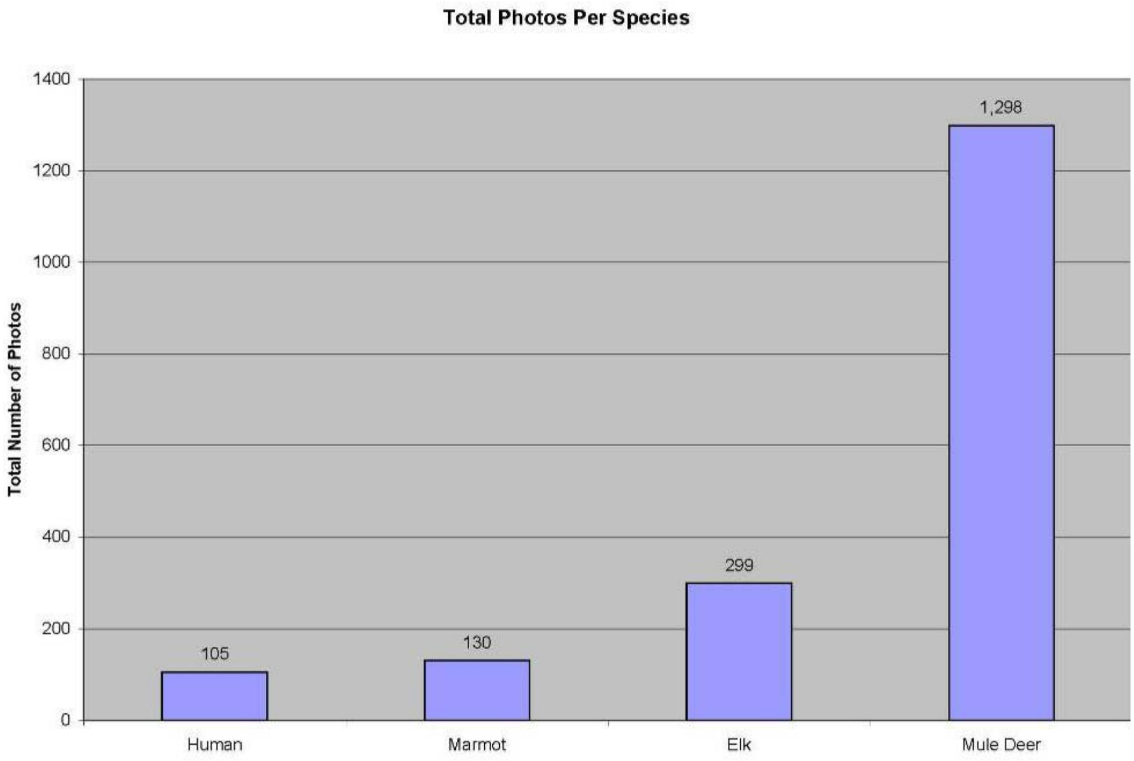


Figure 9 Number of Photographs for all Species, Except Mule Deer and Elk

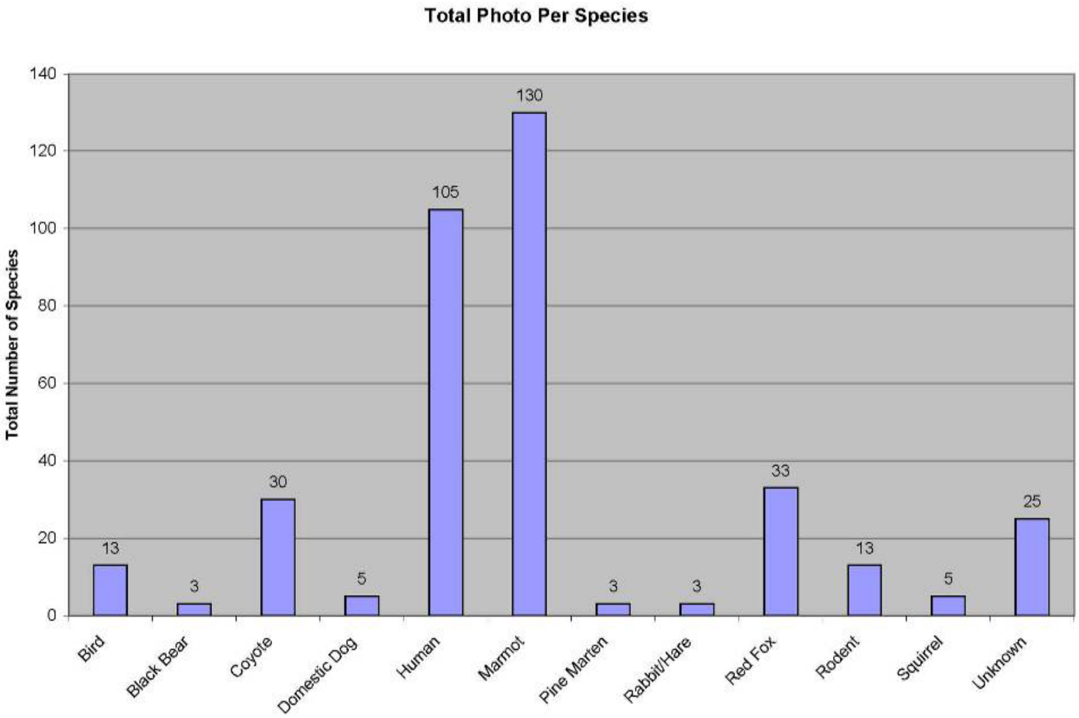
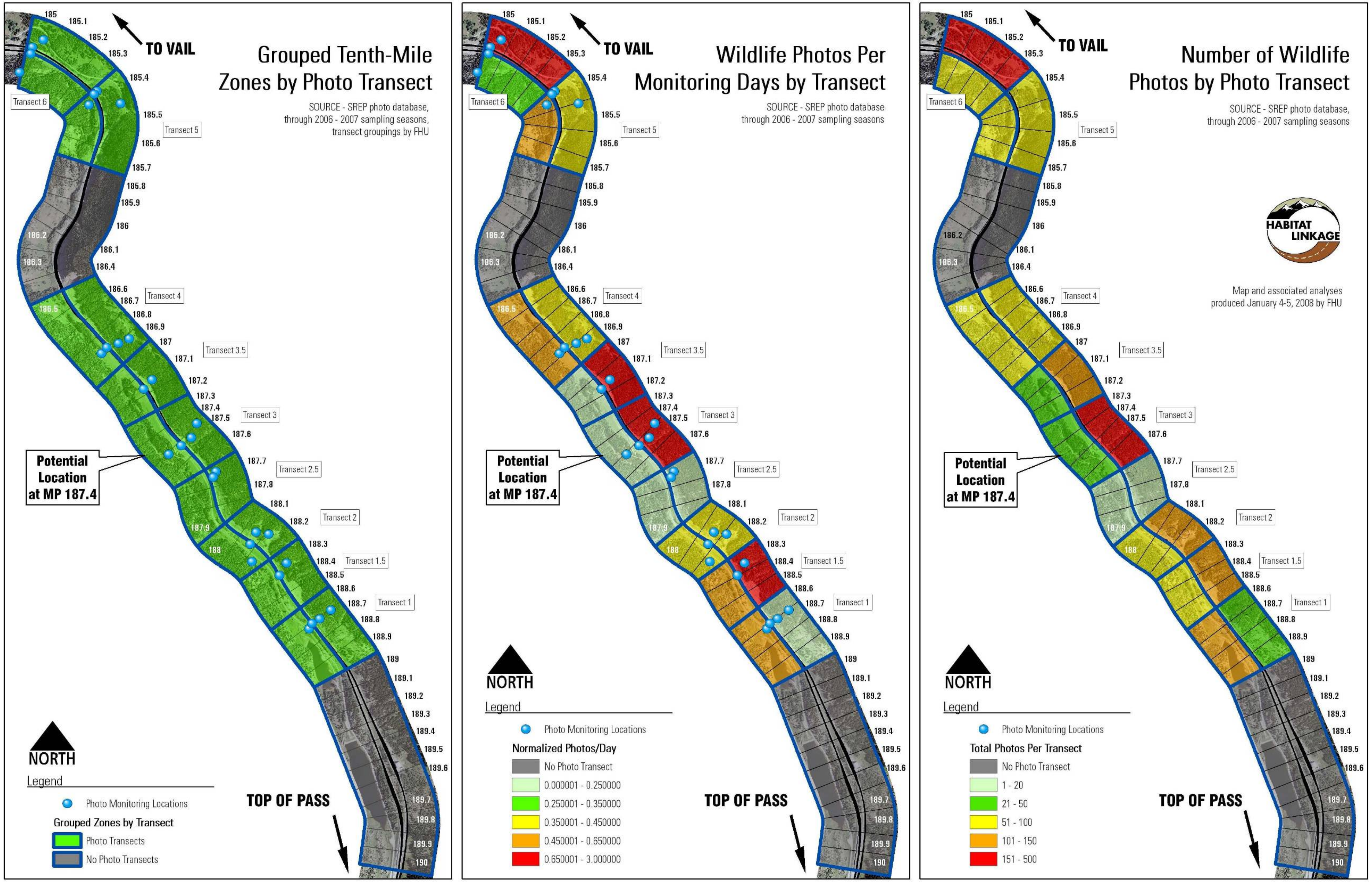


Figure 10 Photographic Data Presented Geographically



Grouped Tenth-Mile Zones by Photo Transect

SOURCE - SREP photo database, through 2006 - 2007 sampling seasons, transect groupings by FHU

Wildlife Photos Per Monitoring Days by Transect

SOURCE - SREP photo database through 2006 - 2007 sampling seasons

Number of Wildlife Photos by Photo Transect

SOURCE - SREP photo database, through 2006 - 2007 sampling seasons

Map and associated analyses produced January 4-5, 2008 by FHU

5.0 LOCATION DETERMINATION

Based on a lynx AVC and its apparent favorable engineering characteristics, a preliminary site for the crossing structure was identified at mile marker (MM) 187.4 prior to the selection of a consultant.

Utilizing the extensive data and information collected and discussed in Section 4.0, the Project Team considered the preliminary site (MM 187.4) to determine if it is a suitable location for the wildlife overpass. Additionally, other sites along the Study Area were also analyzed for suitability for the overpass structure. The Project Team determined that the preliminary site (MM 187.4) was a viable location on West Vail Pass for the overpass crossing structure. However, the Project Team called upon the input from the Wildlife Panel prior to finalization of a structure location.

During the Wildlife Panel meeting, the group discussed various merits and disadvantages of the preliminary site for the structure at mile marker 187.4. The consensus from the Wildlife Panel is that when considering the entirety of West Vail Pass, the site at mile marker 187.4 is the preferred location for the overpass structure because of the engineering characteristics of the site and the wildlife use of the site appears to be high in that area.

The following characteristics were cited as supporting the placement of the structure at MM 187.4:

- The management of the area as a landscape linkage
- The lack of human use (recreational)
- General terrain features on the south side of the pass lead animals to general area (natural funneling effect)
- A natural drainage to Black Gore Creek occurs in the area
- Site is shown to have relatively high wildlife activity (Barnum (2003) Crossing Zones and high number of wildlife photos).
- Target species use
- Suitable engineering characteristics
- The physical nature of the site allows for engineering adjustments that would not have significant effects to wildlife usage of the structure.

6.0 STRUCTURE OBJECTIVES AND TARGET SPECIES

Based upon the information presented in the collected data and input from the Wildlife Panel, target species were identified. Eleven target species were identified. The target species were identified for their likely presence in the study area and habitat/crossing characteristics that might affect the characteristics of structure, but also for the pre- and post-construction monitoring. Target Species for project area.

- Elk
- Mule Deer
- Bighorn Sheep
- Mountain Goat
- Moose
- Black Bear
- Lynx
- Coyote
- American Marten
- Marmot
- Snowshoe Hare

7.0 DESIGN FEATURES FOR THE STRUCTURE

During the initial design process, the Project Team developed recommendations for several important elements that will influence the overall efficacy of the wildlife overpass structure, including width, vegetation/soil requirements, techniques to reduce noise and visual disturbance on the structure, and fencing needs.

These design elements assists in the later stages of the engineering process for the structure. The goal of this process was to focus on the challenging design issues from both the biological and engineering perspectives. The Wildlife Panel was asked to provide information and/or suggestions on the preliminary design criteria based on their agency’s jurisdiction, wildlife expertise, and/or unique knowledge of the Vail Pass area. The feedback received from the Wildlife Panel was reviewed and incorporated by the Project Team.

Each subsection below addresses a unique design criteria associated with the structure and begins with a series of questions that focused the discussion and development of the design criteria. For each topic a brief background, considerations, and the recommendations are presented.

7.1 STRUCTURE WIDTH

- What target species has the greatest width requirement?
- Is there an ideal width versus a minimum structure width?
- Are there any landscape features that may dictate the width?

7.1.1 Background

There are several critical elements in designing a major wildlife overpass (or green bridge), one of which is the width of the overpass. Width is one element that influences the structure’s ecological efficacy, including the type of wildlife species and amount of wildlife use of the structure. The width can directly or indirectly affect elements such as the amount of traffic noise, nighttime light levels, and other factors that result in the structure’s “naturalness.” One of the key elements in any highway wildlife crossing is making the structures as natural as possible, so that wildlife do not avoid use. The width also allows for some ecological diversity to occur on the overpasses surface. These might include herbaceous vegetation, shrubs and forested portions and placement of woody debris (logs and stumps) to encourage small animal use.

A number of experts from the United States, Canada, and Europe were contacted about various aspects of the potential width for the overpass structure. These experts included ecologists, engineers, and research scientists with experience in various aspects of designing wildlife crossing structures. Europe has the largest number of green bridges (as they are referred to there) and more experience in various management considerations than in North America. In North America, the overpasses on the Trans-Canada Highway in Banff National Park, Alberta, Canada deal with many similar species and situations common to the proposed West Vail Pass Wildlife Overpass.

7.1.2 Width Considerations

Biological

Various widths of overpasses have been built in the United States, Canada, and Europe. Widths of these overpasses vary from less than 5 meters to 870 meters (in Germany). Many of the large animal wildlife overpasses have been built in the 40-80 meter width range. Wildlife overpasses in this width range have been effectively used by moose, elk, European red deer (a relative of the North American elk), brown bear (in Canada and Europe), wolves, mule deer, black bear, cougar, and a variety of forest carnivores such as lynx. Research in Europe has also suggested that structures widths less than 20 meters are used significantly less than larger structures, whereas structures that are 50 to 60 meters are preferable (Forman et al., 2003).

Presently, the two overpasses on the Trans-Canada Highway in Banff National Park, Alberta are 52 meters, span four lanes of traffic, and have been effective for all, or most of, the native large and mid-sized mammals. Elk, mule deer, and moose particularly favor the overpasses, which are three of the target species for the West Vail Pass Wildlife Overpass. Moose and elk are two species that present a design challenge, particularly when highway underpasses are being considered as an option. In Europe, the most difficult species to design wildlife crossings for are ungulates, such as moose, deer, and elk.

The Montana Transportation Department and associated resource agencies selected a 50 meter width for it's first major wildlife overpass to be built in 2008-2009 at Evaro Hill, Highway 93. This overpass will also function for similar species as the West Vail Pass Wildlife Overpass, plus grizzly bear and wolves.

Wider overpass structures may have less highway noise, light, and other potentially disturbing factors. Highway noise and light can also be mitigated through use of fencing and other barriers; however, the barriers themselves can be disturbing to some wildlife. The 52 meter overpasses in Canada appear to mitigate traffic disturbances well and are used by many of the same species of mammals that are target species for the West Vail Pass Project.

Engineering

Cost is an important factor. Structure width also directly affects cost. Cost is often a primary consideration for Departments of Transportation (DOTs), particularly in the United States, when selecting wildlife crossing structure types and dimensions. Transportation agencies attempt to find the least cost solution that serve the intended purposes of population and habitat connectivity. This concern is based on limited funding options available to DOTs to fund the construction of wildlife mitigation measures.

7.1.3 Recommendation for Structure Width

The Project Team recommends a 50-meter (approximately 164 feet) width for the overpass structure. After reviewing the literature and speaking to experts in the United States, Canada and Europe, the consensus is that an overpass 50 meters wide has a high level of assurance of use by the target species. One of the principal decision factors is that many of the wildlife species targeted for the West Vail Pass structure successfully use similar Canadian overpasses. While there are some indications, principally from Europe, that overpasses with slightly less width may suffice, similar species in Europe have been isolated from the North American species for thousands of years. The 50-meter width is recommended to ensure that the West Vail Pass overpass adequately addresses the ecological needs of the target species.

Another consideration for width is that the West Vail Pass is considered a “landscape linkage” for the Central Rocky Mountains. This designation is identified by the USDA Forest Service land management plans and is recognized by other agencies. Being a major landscape linkage, reliability of use is necessary for a wide variety of species that use this linkage area for dispersal activities and other wide-ranging movements.

7.2 SOIL DEPTH/TYPE

- What is the ideal and minimum depth to grown vegetation?
- What type of soil is needed?
- What are the drainage requirements of the plants?

7.2.1 Background

The soil depth and soil quality on the West Vail Pass overpass structure are critical components that will influence the successful establishment of vegetation on the overpass. Establishing a range of native vegetation on the structure will create the desired extension of habitat on either side of I-70 and will affect the overall use of the structure. The soil characteristics and depth will depend on the type of vegetation planned for the structure. Soil quality was identified as the most important factor for vegetation success on overpass structures. Soils used on these structures must contain good organic matter (Leeson, 2008).

The depth of the topsoil in a natural sub-alpine forest is shallow, causing tree roots to grow laterally in search of nutrients. Eventually, because trees in their natural environment grow closer together, the root structures will grow together, providing support and securing trees to the ground. In a designed planting, trees do not have the opportunity to develop such a root structure and require substantial root balls for support.

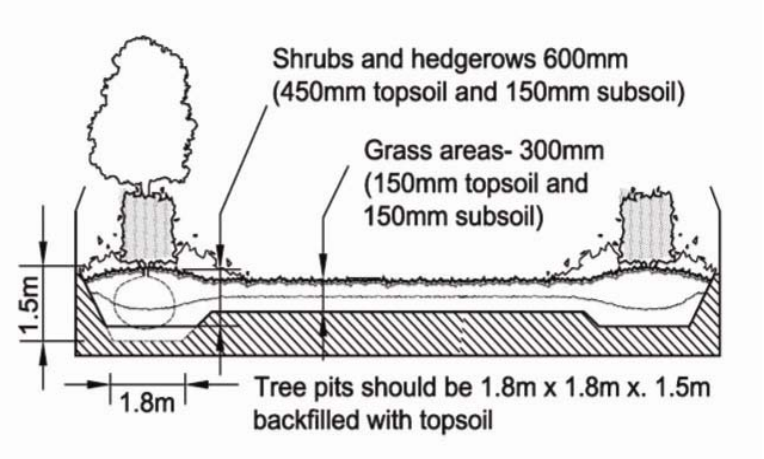
7.2.2 Soil Depth Considerations

According to research and conversations with professionals familiar with vegetated wildlife overpasses or specialists in green roof technology, the most common soil depth range is 4 inches to 6.5 feet. Depth is dependent on the vegetation type on the structure. For example, 4 to 6 inches of soil is the minimum requirement for sedums, lawn, and small clumping grasses and 18 inches for shrubs. Trees require a minimum depth to encompass their root ball (see illustration below). The depth of the root ball will vary depending on the species of tree and the size of tree when planted. For trees, a minimum of five feet is recommended.

7.2.3 Recommendation for Soil Depth

The Project Team recommends a minimum of five feet of soil based on the vegetation requirements (see **Section 7.3**). This includes both sub-soil and surface soil. The Project Team recommends that the fill material be similar to the existing native soil adjacent to the site. Soil temperature may vary and will not emulate the adjacent native soil. To insulate the soil and vegetation, it is recommended that 4-inch-thick rigid foam is applied to the base of the structure (Leeson, 2008).

The Project Team determined that no additional drainage requirements for sustaining vegetation on the structure are required. The Project Team's recommendation that once water has percolated through the proposed five foot soil depth, no other detention of drainage is required.



A combination of appropriate soil depth and anchoring will reduce the risk of trees falling. For example, trees could be anchored to the bridge structure using a deadman underground guying system (see **Figure 11**).

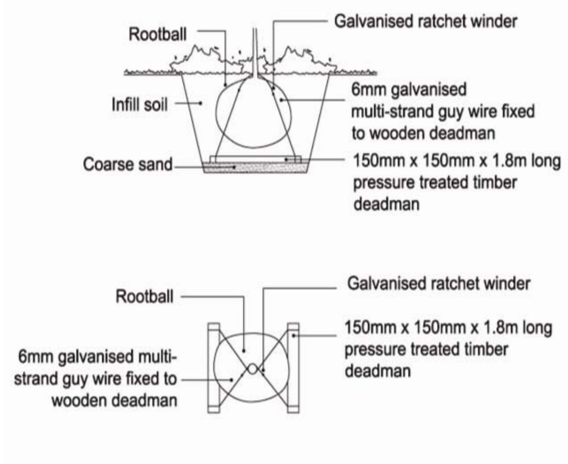


Figure 11 Illustration of Tree Anchoring System

*****Recommended soil profiles for planting on bridge structures.

*****Illustration showing the use of deadman underground guying system to secure large trees to the bridge.

7.3 VEGETATION

- What type of vegetation can grow on the soil profile?
- What level of cover needs to be provided on the structure?
- Will landscaping need to occur on the structure approaches?
    - If so, what type of vegetation and level of cover should be provided?
- What species mixture can/should be included?
- Are there any USDA Forest Service requirements for genetic stock, etc.?
- What are the drainage requirements of the plants?
- Are there any species-specific vegetation/cover requirements?

7.3.1 Background

The type and amount of vegetation on the West Vail Pass overpass structure and approaches (i.e., areas leading up to the structure) will influence the structure's ecological efficacy. Mimicking the characteristics of the surrounding habitat encourages use by the greatest variety of plant and animal species including, soil microbes, insects, reptiles, amphibians, and large and small mammals.

The type and amount of vegetation considered for the structure and approaches is dependent on the target species, which have different cover preferences and requirements for activities such as foraging, daily and seasonal movements, and dispersal. Providing habitat that meets the basic needs of target species will also likely meet the needs of other species that depend on the same habitat (see **Table 1**).

Table 1 Dispersal or Travel Habitat Requirements for Target Species

Target Species	Dispersal or Travel Habitat
Canada Lynx (*Lynx canadensis*)	Prefer to travel in habitat with trees or brush, or along edges. Avoid large openings. Not well studied related their use of wildlife crossings, but have been documented using underpasses and overpasses (Hardy et al., 2007).
American (Pine) Marten (*Martes americana)*	A habitat specialist. Travel through the tree canopy or on the ground. Prefer habitat with large or mature trees. Food, such as tree squirrels are often associated with mature forests. Avoid large openings. American martens have been documented using both underpasses and overpasses (Clevenger, Chruszcz, & Gunson, 2001; Clevenger et al., 2002). Not well studied related to their use of wildlife crossings.
Mule Deer (*Odocoileus hemionus)*	Are considered habitat generalists. Occupy a wide variety of habitats and elevations – often travel along forest edges. Prefer habitats with an interspersion of forests, shrubs, and various open forb-lands and grasslands. Mule deer have been documented using underpasses and overpasses (Clevenger et al., 2002; Clevenger & Waltho, 2000, Clevenger & Waltho, 2005; Gagnon, Dodd, Schweinsburg, & Manzo, 2005. Prefer overpasses and structures with large openings (Clevenger et al., 2002; Clevenger & Waltho, 2000; Clevenger & Waltho, 2005; Hardy et al., 2007).
Elk *(Cervus elaphus Canadensis)*	Are considered habitat generalists, often occupying semi-open forests or forest edges adjacent to parks, meadows, and alpine tundra. Will use secure openings, including large openings such as meadows, prairies and agricultural fields. Elk are usually herd animals. Are sensitive to human use and may avoid some types of wildlife crossings. Elk have been documented uses underpasses and overpasses (Clevenger et al., 2002; Clevenger & Waltho, 2000, Clevenger & Waltho, 2005; Gagnon, Dodd, Schweinsburg, & Manzo, 2005. Prefer overpasses and structures with large openings (Clevenger et al., 2002; Clevenger & Waltho, 2000, Clevenger & Waltho, 2005; Gagnon, Dodd, Schweinsburg, & Manzo, 2005; Hardy et al., 2007).

Table 1 Dispersal or Travel Habitat Requirements for Target Species (continued)

Target Species	Dispersal or Travel Habitat
Coyote *(Canis latrans)*	A habitat generalist that occupies many habitats, ranging from grassland and deserts to urban areas; lush pastures and overgrazed pastures. Use cover for daytime resting and den sites. Will occupy and travel across large openings or areas with interspersions of cover and openings. Generally tolerant of human presence. Coyote have been documented using both underpasses and overpasses (Clevenger, Chruszcz, & Gunson, 2001; Clevenger et al., 2002; Haas, 2000; Lyren & Crooks, 2001).
Bighorn Sheep *(Ovis Canadensis)*	Use habitats dominated by grass, low shrubs near rocks, cliffs, or steep terrain. Often travel through forested and semi-open habitats. Not well studied related to wildlife crossings, but can be tolerant of humans. Have been documented using underpasses (Clevenger et al., 2002; Hardy et al., 2007). Bighorn sheep will likely use well-designed overpasses
Mountain Goat *(Oreamnos americanus)*	Occupy high-elevation tundra, grassy slopes, and alpine and subalpine meadows intermixed with forest. Often dominated by grasses, sedges, rushes, sagebrush, huckleberry and other high-elevation shrubs and forbs. Generally not considered tolerant of humans. Not well studied related to use of wildlife crossings, but have been documented using underpasses (Hardy et al., 2007). Mountain goats would likely use well-designed overpasses.
Snowshoe Hare *(Lepus americanus)*	In Colorado, restricted to the mountains, commonly in or near dense stands of montane or subalpine forest and alpine tundra, areas with dense understory, or a layer of plants below the main canopy of forest, created by young trees or tall shrubs. Often disperse when high populations occur or when food supplies diminish (in cycles). Snowshoe hare have been documented using both underpasses and overpasses (Clevenger, Chruszcz, & Gunson, 2001; Clevenger et al., 2002). Not well studied related to use of wildlife crossings, especially those designed with dense brush or understory.
Black Bear (Ursus americanus)	A habitat generalist. Often tolerant of human presence. Uses shrublands and montane forests, subalpine forests at moderate elevations; rugged terrain and dense shrubs provide escape cover and den sites. Often uses and travels along edges. Habitat diversity and productivity is important; prefers mesic over xeric areas – and high productivity fruit or mast producing shrublands. Grasslands, forb-lands and prey are seasonally important. Black bear have been documented using underpasses and overpasses (Clevenger et al., 2002).
Moose *(Alces alces)*	Use a variety of forested areas, often close to lakes and other riparian habitats; areas of abundant, high-quality browse, young forest stands with deciduous shrubs and forbs for summer feeding, mature closed-canopy forests for shelter in the winter; shrub fields the most critical community. Intermediate tolerance to human presence. Use of wildlife crossings can be problematic. Often travel through forested areas or along forest-shrub edges. Prefers structures with large openings (Clevenger et al., 2002).
Yellow-Bellied Marmot *(Marmota flaviventris)*	Travel and dispersal habitat is unknown. Generally uses open habitats such as alpine meadows, pastures and forest edges associated with large, angular rocky areas and large-sized talus.Have been documented using small mammal shelves in culverts (Foresman, 2004).

7.3.2 Vegetation Considerations

The selected location for the habitat linkage is characterized by the vegetation types found within the subalpine life zone between 9,000 and 11,400 feet (treeline) in elevation. This zone is dominated by coniferous forest, meadows, riparian habitats, and shrublands.

Vegetation on the overpass and approaches should mimic the surrounding existing native vegetation. Native plant species and form will be used to emulate the preferred habitat of the target species, providing for a diversity of vertical and horizontal structure also used by other species. Vegetation continuity will provide a natural transitional habitat corridor, allowing animals to move across I-70.

The vegetation for the overpass structure should include a diversity of species and types including grasses, forbs, shrubs, large trees, small trees, and woody debris, such as logs and rocks that provide attractive travel corridors and cover for smaller animals.

Trees are an important component of wildlife habitat diversity and will help connect habitat on both sides of the structure and provide forage and cover for many species. It is important to note that the trees planted on the structure will generally reach a height of only 2 to 3 meters, rather than their normal mature height of 20 to 60 meters, due to the constraints of the structure and available water. This reduced height, combined with the creation of buffer zones along the edges of the structure, should eliminate the potential for trees to fall from the structure. In addition, planting trees in naturalized groupings will help to redirect wind over the canopy, reducing the potential for toppling of individual trees. Another method is to anchor the trees to the bridge structure using a deadman underground guying system or staking.

7.3.3 Recommendation for Vegetation

The following is a preliminary list of recommended vegetative species (dominant species are in bold), including trees, shrubs, forbs, and grasses for the overpass:

- Trees – **Subalpine fir** (*Abies lasiocarpa*), **Engelmann spruce** (*Picea engelmannii*), **Lodgepole pine** *(Pinus contorta)*
- Shrubs – Gooseberry currant (*Ribes montigenum*), Russet buffaloberry *(Sheperdia canadenis),* Red elderberry *(Sambuca racemosa),* Bearberry *(Arctostaphylos uva-ursi),* Trumpet gooseberry *(Ribes leptantheum),* Wax current *(Ribes cereum)*
- Grasses – Tufted hairgrass (*Deschampsia cespitosa*), Thurber's fescue (*Festuca thurberi*), Alpine bluegrass (*Poa alpina*), Mountain brome (*Bromus marginatus*), Idaho fescue (*Festuca idahoensis*), Slender wheatgrass (*Elymus trachycaulus*)
- Forbs – **Heartleaf arnica** (*Arnica cordifolia*), **Fireweed** (*Epilobium angustifolium*), Bluebell (*Mertensia ciliate*), Lousewort (*Pedicularis* sp.), Lupine (*Lupinus* spp.), **Richardson's geranium** (*Geranium richardsonii*), Prairie smoke (*Geum triflorum*), Buckwheat (*Eriogonum* ssp.), Jacob's ladder (*Polemonium pulcherrimum),* Pussytoes *(Antennaria* ssp.*),* Sticky purple geranium *(Geranium viscosissimum),* Bluemist penstemon *(Penstemon virens), Whipple's penstemon (Penstemon whippleanus),* Slender cinquefoil *(Potentilla gracilis).*

The recommended composition of vegetation should consist of a mosaic of trees, shrubs, grasses, and forbs. The recommended composition of tree cover ranges from 20 percent to 50 percent, with the remaining habitat consisting of a mix of shrubs, grasses, and forbs.

Plant material for the structure may come from a variety of sources, but preferred sources include seed banks established from local plant materials and transplanted trees salvaged from areas of disturbance, such as local power line or right-of-way clearings. If seed banks are selected, collection should begin early to allow time for propagation or recollection in case some seed sets are not viable. Establishing a seed bank will not only service this project but will also provide replacement plant material if there is failure. In addition, a seed bank may help develop native plant material for the adjacent forest (Kratz, 2008). It is expected that plants on the structure will experience a certain amount of mortality due to natural circumstances. Fallen trees may be kept on the structure to provide habitat for some wildlife. The Forest Service may also allow plants from the general area to be used on the structure with a special-use permit, and may also be able to assist or provide seeds, seed stock, and other planting material for the structure landscaping.

A long-term management plan will be an important component for the success of the vegetation on the overpass structure. The management plan should include invasive weed monitoring and control, supplemental watering until plant establishment, habitat enhancement, coordination with adjacent land uses, and monitoring and replacement of vegetation to ensure that proper successional stages are achieved.

7.4 VEGETATION LAYOUT

The goal of the landscape concepts presented is to provide a diversity of habitat structure that meets the needs of the selected target species. In addition to meeting most of the dispersal and habitat requirements, the connectivity of the structure to the adjacent landscape is also important. Three landscape concepts were created that address the dispersal and travel habitat to various degrees while taking into consideration climatic conditions, vegetative cover, and proximity to existing corridors (e.g. riparian area on the north side of the structure). All three concepts have a vegetative composition of tree cover that ranges from 15 to 30 percent with the remaining habitat consisting of a mix of shrubs, grasses, and forbs.

Tree and shrub species are not designated on the concept plans. However, general growth habits and adaptability concepts can be applied. For example, Lodgepole pine provides a good windbreak and could be planted toward the exterior portion of the tree groupings facing the direction of the up-slope winds. The Lodgepole pine may also provide some shade in which the Engelmann spruce and Subalpine fir are best adapted.

7.4.1 Criteria for Vegetation Survival

Vegetation survival and the ability for the trees, shrubs, and grasses/forbs to sustain themselves will be dependent on a variety of factors including: site conditions and site preparation; growth medium, water availability, planting techniques, time of planting; monitoring for disease/illnesses and/or injuries; preventing soil compaction, maintenance, and invasive weed control. For example, diseased or injured trees may be more prone to windfall. Densely planted trees will compete for nutrients, water, and rooting volume, but densely planted trees will also be more protected from in renewing a stand by creating gaps in the forest floor where new seedlings can become established.

Soil composition and depth will be an important component for vegetation survival on the bridge structure, particularly for the trees. Discussions with Dr. Bruce Leeson (retired Ecological Scientist, Parks Canada) suggested that the primary difference in tree survival on wildlife overpasses in Canada was the quality and quantity of topsoil. The structure with the best tree survival had a greater depth and quality (more organic matter) of topsoil. Topsoil on the West Vail Pass Wildlife Overpass should be at least one foot in depth, with a similar pH as the surrounding native soil (being slightly acidic) and have an adequate amount of organic matter. Vegetation survival is not easily quantified based on unknown factors. However, the most appropriate growing conditions should be provided for successful vegetation establishment.

Trees and Shrubs

The first step to successful plant establishment is to start with a healthy, well-grown plant. Regardless of the source of the plants, care in transporting them to the site is crucial to prevent injury. If plants are purchased from a nursery, careful inspection for damage or disease is important before purchase. If salvaged plants are going to be used they should be salvaged when they are dormant (spring or fall) and planted as soon possible to maximize establishment. Transplanting dormant plants reduces the demand for water and allows time for the roots to acclimatize before the onset of summer heat/dryness or freezing temperatures of winter. Trees and shrubs can be purchased as container grown, ball and burlapped, and bare root. Depending on the type selected there may be different criteria for planting. For example, bare root plants are small and have no soil around their roots. It is important to plant bare root plants when they are dormant to prevent their roots from drying out. If this is not possible, their roots must be kept moist until planted. Planting the plants at the correct depth, at the level of original soil level, may also help prevent problems or death later. Protecting the plants after they are planted is also important to prevent stress/damage by wildlife browsing, wind, moisture loss, and sun. Watering the plants sufficiently for the first couple of years will prevent plants from drought stress and failure.

Grass and Forbs

Seed mixes will be used for this project so the time of seeding will be important. The planting season selected should take advantage of natural moisture because this will be a non-irrigated site with only temporary supplemental watering. Seed establishment and growth success depends on temperature and precipitation. Seeding should occur when the temperature is above freezing and precipitation is high. The type of seasonal growth patterns of the species selected should also be taken into consideration. For example, grasses have two seasonal growth patterns; cool season and warm season. Cool season grasses begin their growth in late winter/early spring and bloom in early summer. Warm season grasses begin their growth in late spring/early summer and bloom in late summer/early fall. Planting both cool season and warm season grasses will provide diversity and cover throughout most of the seasons. It will be important to seed the site as soon as final grading and topsoil placement has occurred to prevent erosion and invasive weed establishment. A protective mulch should be added to the site after seeding until seed germination to protect the seeds and soil from erosion, sun, moisture loss, and wind.

7.4.2 Layout Concept Recommendation

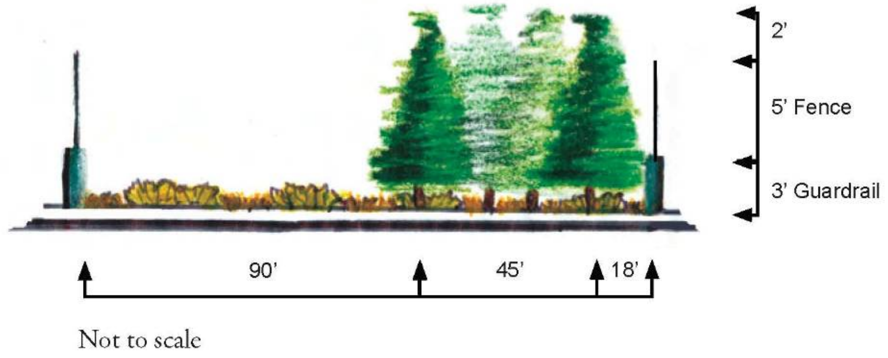
Three vegetation layouts were considered by the Project Team. The following layout presents the final recommended vegetation layout for the overpass structure (see **Figure 12** and **Figure 13**).

A linear grouping of trees is located on the east side of the structure providing some buffering from the highway noises and lights below. This planting effect creates a forested edge leaving the remaining structure open. The open areas are comprised of shrubs, grass, and forbs. A strip of woody debris (e.g. stumps, logs) and small rocks will extend along one side of the structure from approach to approach. The function of this debris is to provide protective cover for smaller mammals using the structure.

The following represent the primary characteristics associated with the vegetation layout:

- Tree cover: approximately 16 percent
- Shrubs, grasses, forbs cover: approximately 84 percent
- 101 trees total, including area of disturbance off the deck of the bridge. Note: this may be dependent on final grade of the approaches and the ability to accommodate trees.

Figure 12 Typical Vegetation Section



*Looking north, dominant surface water flows toward the structure's southwest corner.

Figure 13 Aerial View of Vegetation Layout

7.5 ROADWAY NOISE AND VISUAL DISTURBANCE

- Does noise need to be minimized on the structure and approaches?
- Does the structure need to have specific USFS visual requirements?
- What techniques can be implemented to reduce noise and visual disturbance to wildlife?

7.5.1 Background

Noise and visual disturbance from moving vehicles has the potential to stress certain wildlife species and has the potential to affect movement patterns and use of wildlife crossing structures. The Project Team concluded that it is important to minimize disturbance on the overpass structure to encourage wildlife use. Disturbances include noise and lights from moving traffic on I-70.

7.5.2 Considerations

The team anticipates that traffic noise and visual disturbance to wildlife using the crossing can be minimized by the structure design itself, and the reduction will vary based on where the wildlife travel on the structure. Much of the traffic noise will be effectively blocked by the mass of the structure. Wildlife using the edge of the crossing structure would be more exposed to disturbances from the traffic than wildlife using the interior of the structure. The reduced exposure to noise and traffic created in the “interior zone” of the structure may be attractive to wildlife that are wary of human disturbance.

Several engineering design strategies to reduce the levels of disturbance on the West Vail Pass overpass structure were considered. These strategies included: natural berms, solid walls, Texas rail type concrete median barriers, and structure grading strategies. Fencing also needs to be provided for the protection of the travelling public and animals.

Berms

One strategy that the Project Team considered consists of placing berms and game fencing along the sides of the structure. This technique has been used on the overpasses on the Trans-Canada Highway in Banff National Park, Alberta, Canada and also on some of the European overpasses to reduce noise and visual disturbance. Natural berms are typically vegetated and constructed of earthen material, although recycled materials can also be used. Therefore, structures using this strategy maintain a natural appearance. In other applications, berms have been constructed from recycled tires to reduce highway noise. The overpasses in Banff have one meter high earthen berms constructed along each side of the structures, in conjunction with game fencing. The berms have a 2:1 slope ratio and a 1.5 meter flat top (Mcquire, 2008). Depending on the structure width, using natural berms can take up valuable space on an overpass structure if wildlife movement is limited to the non-bermed areas. However, in Banff, some wildlife, including elk, use the flat top of the berms as a travel surface. Natural berms also increase the load on the structure, which can change the engineering requirements for the overpass.

Solid Fencing

Another strategy is placing solid fencing along the sides of the structure, a technique that is used on some of the overpasses in Europe as a means to reduce noise and visual disturbance. One issue with solid fencing is the possibility of creating a “corral” effect or the appearance of a confined zone of movement on the structure. The potential to create this effect is dependent on the width and length of the overpass structure, but overall can cause avoidance of, or reluctance of wildlife use of crossing structures by some species, such as elk. An additional concern is that solid fencing could detract from the natural appearance of the structure. A specific concern with the use of solid fencing on the West Vail Pass overpass structure is that it could exacerbate snow drifting on the structure during the winter.

Concrete Barriers

Another strategy considered consists of placing a 3-foot concrete barrier above the cement foundation sides of the structure and 5 feet of game fencing mounted on top of the barrier. The concrete barrier would not extend onto the structure approaches. The raised 3 foot barrier will help to alleviate some of the noise and visual disturbance from the roadway below the bridge. Using an analytical noise model, it was estimated that a 3 foot concrete barrier would reduce traffic noise levels by up to 5 decibels near the edges of the structure. It is believed that raising the solid barrier any higher would not provide any more noticeable improvement for sound and/or visual disturbances. Keeping the concrete barrier elevation at 3 feet should keep the snow drifting potential on top of the bridge to a manageable level. The game fencing is not expected to contribute significantly to snow drifting, due to the general openness of the fence pattern. To maintain a natural appearance on the overpass structure, the raised concrete barrier and can be concealed with dense vegetation. Additionally, the concrete barrier itself can be treated with textures and colors that would help it blend into the natural landscape.

Grading Concept

A proposed grading concept on top of the bridge that is believed to offer some benefit to the target species was also considered and would consist of a continuous swale extending over the full width of the bridge, and continuing along the entire length of the structure. The swale would maintain an elevation along the edges of the bridge that is relatively higher than at the center of the bridge. However, this would be a difficult concept to develop, considering the proposed structure type and the proposed width of the structure (150 +/- feet). The bridge is anticipated to be constructed similarly to a majority of typical highway bridges, which will consist of precast concrete girders with a concrete deck on top of the girders. The soil required for planting would be placed on top of the concrete deck. All of the girders over the full width of the bridge will be at approximately the same elevation to optimize the efficiency of the girders and the bridge deck system. One option for creating a significant elevation difference between the center of the bridge and the sides is to raise the outer girders relative to the center girders. This is not very practical for bridge construction, as the efficiency of the girder and deck system is compromised significantly. A second alternative for creating a swale effect would be through increasing the soil depths from the prescribed minimum at the center of the bridge, to depths several feet higher along the sides of the bridge. The proposed minimum soil depth on any portion of the structure is 4 to 5 feet, which is a significant load for the proposed bridge system. Adding additional soil depth at the sides of the bridge will add significantly to the weight on the structure, and will be detrimental when pursuing an efficient and affordable bridge design.

7.5.3 Recommendation for Roadway Disturbances

The Project Team recommends using a combination of concrete barrier and game fencing along the edges of the structure. The primary reason is that the barrier/fence combination does not require the high fill demands compared to the earthen berms, and still reduces noise and visual disturbance. The effectiveness of a relatively level surface on the structure, with modestly raised berms and concrete barriers described above will be considered for the final grading on this structure.

7.6 FENCING LENGTH & LAYOUT

Fencing is an important design element that can influence the effectiveness of the West Vail Pass overpass structure. Fencing is used to help guide wildlife to crossing structures, and helps prevent animals from entering the right-of-way (Clevenger, Chruszcz, Gunson, & Wierzchowski, 2002; Forman et al., 2003; Hardy et al., 2007). Fencing will also be placed on the top edges of the overpass structure itself to ensure animals remain on the structure. Routine fence maintenance is essential to maximize the effectiveness of the fencing, as the integrity of fencing can be affected by multiple factors, such as soil erosion, rock fall/avalanches, vandalism, damage from trees, vehicle accidents, and animals digging underneath (Clevenger et al., 2002).

7.6.1 LENGTH

Background

The length of fencing used in conjunction with wildlife crossing structures across the U.S., Canada, and Europe varies considerably, ranging from continuous stretches of fencing along highway rights-of-way to minimal stretches of “wing fencing” extending from structure approaches. Fencing length requirements are based on biological criteria (i.e., target species, AVC rates, movement patterns, topography, and man-made barriers).

In many instances, fencing is placed continuously throughout a corridor as a part of an overall system of wildlife crossing structures. For example, in Banff National Park, Alberta continuous fencing along the Trans-Canada Highway links together a series of large wildlife crossing structures. Currently, the distance between crossing structures ranges from 0.12 to 2.9 miles (Clevenger et al., 2002).

Continuous fencing over large stretches of highway may not be recommended in areas with low AVCs and where stable wildlife populations are present. Fencing in these areas increases habitat fragmentation effects and can further restrict natural wildlife movements (Clevenger, 2002; Jaeger & Fahrig, 2004). For projects that do not necessitate continuous fencing, structures are often initially designed with a conservative amount of “wing fencing”. This wing fencing is designed to provide a mechanism that funnels animals onto the structure. Wing fencing length recommendations vary from ¼ to ½ mile or more when carnivores, deer and elk are target species. However, fencing decisions are inherently site-specific and dependent on factors such as local topography and the target species the structure is aiming to accommodate (Ruediger, Wall, & Wall, 2005; Bastings, 2007).

Fencing Length Considerations

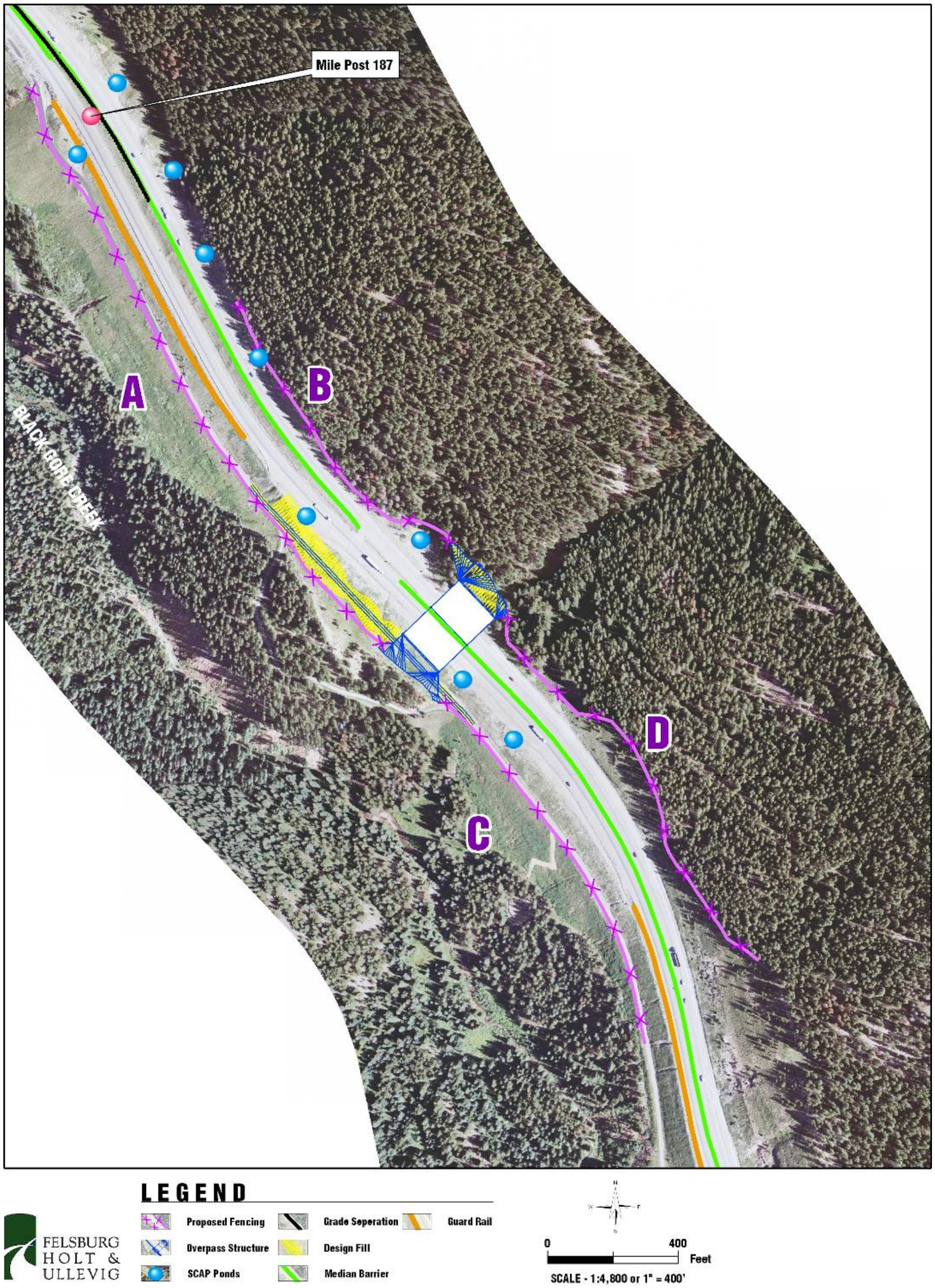
Several factors were considered to determine the preliminary fence lengths for the West Vail Pass overpass structure, including: topography, vegetative cover, the existing highway configuration, and wildlife activity within the corridor to identify areas for logical fence ending points. These areas included existing grade separated areas, steep topography (e.g., rock faces, cliffs), or areas with dense vegetative cover. These areas were considered logical ending points because it was assumed that wildlife could not easily access the right-of-way from these locations.

Locations of “crossing zones” (CZ) and track records (TRs) previously identified in a CDOT research study were also assessed to help determine the preliminary fence length for the West Vail Pass overpass structure (Barnum, 2003). CZs are highway segments with the highest probability of crossing activity, and TRs indicate activity near the highway, including movements along the roadside (Barnum, 2003).

Recommendation for Fencing Length

The Project Team does not recommend continuous fencing through the entire study area (MP 185 – 190), or extending the fencing more than ½ mile from the overpass. Some members of the Wildlife Panel requested that fencing not be continuous and extend to natural or man-made barriers. This decision was based both on the relatively low AVC rate along this stretch of highway (Colorado State Patrol & CDOT Accident Data 1986 to 2006) as well as on site visits by the Project Team. The preliminary length of fencing on both sides of the West Vail Pass overpass structure does not need to extend farther due to the extreme changes in topography (see **Figure 14**).

Figure 14 Display of the Final Fencing Extents



Note: Multiple impediments to wildlife movement (existing guard rail, median barrier, and grade separation).

7.6.2 LAYOUT

Fencing Layout Considerations

The fence layout and design associated with the West Vail Pass overpass structure is dependent on many factors. Several potential fencing alignments were developed based on the following considerations:

Biological Issues

Biological elements that were considered that could influence structure use and the final fencing layout include: location relative to vegetative cover, human disturbance and wildlife/human interaction, location of potential attractants (e.g. Sediment Control Action Plan ponds [SCAP ponds] along the highway, and potential fence gaps.

Vegetative cover is an important component of habitat for many species, it provides forage and protection from predators, visually shields the highway, and dampens noise. The placement of fencing on the south side of the multi-modal trail decreases the potential for human disturbance. The SCAP ponds within the corridor act as attractants to ungulates (evidenced by trap-camera photographs taken by Southern Rockies Ecosystem Project).

Installation/Maintenance

Engineering elements considered that influence the fencing layout included: accessibility of the fence for repairs, installation constraints due to topography, installation costs, and winter snow removal activities. Maintenance crews would have to spend more time and resources installing and repairing the fence if it is farther from the highway or multi-modal trail, especially in areas with steeper terrain. The steepness of terrain will also affect the amount of time it will take to install the fence, especially if vegetation needs to be cleared, which will increase costs of installation and maintenance. If fencing is placed too close to I-70, winter snow removal would likely damage the fencing and could also be damaged by vehicles accidentally leaving the roadway.

Recreation

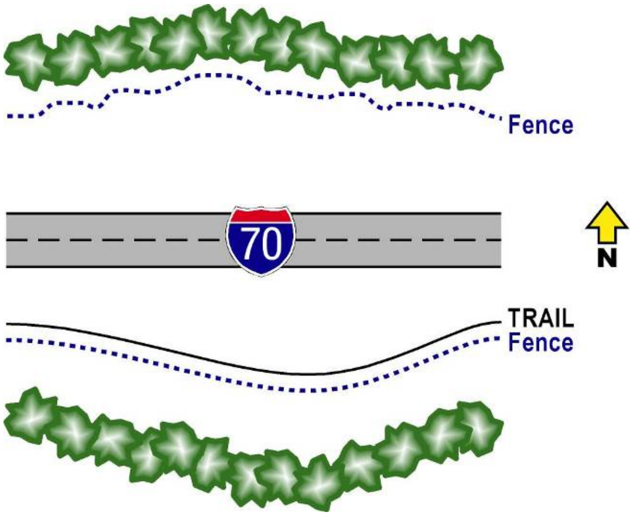
The primary issue related to recreation and the placement of the fence is in relation to the multi-modal trail on the south side of I-70. Maintaining the current alignment of the multi-modal trail is not preferred because gaps would be created at the intersection of the trail and fence. Wildlife could enter the right-of-way at these locations and could decrease structure use by wildlife.

Elements that affect recreational use include limited access to the White River National Forest (WRNF). The accessibility to unmarked trails in the WRNF by hunters and other recreational users may be limited by the installation of fencing near the highway. However, impromptu parking along the interstate is discouraged by both the WRNF and CDOT. Fencing would prevent this practice. Fencing may also inhibit unauthorized snowmobile access from the multi-modal trail. However, by locating the fence adjacent to the trail, this would result in visual impacts to the recreational users of the trail.

Recommendation for Fencing Layout

The recommendation is to place wildlife fencing along the south edge of the multi-modal trail (south of I-70) and along the treeline on the north side of I-70 (see **Figure 15**). The fencing on the south side of I-70 and south of the multi-modal trail is advantageous because it minimizes human disturbance and potential human/wildlife interaction due to the relocation of the multi-modal trail.

Figure 15 Schematic of fence in relation to I-70



This configuration would include the relocation of the multi-modal trail underneath the span of the overpass structure. While this will move the trail closer to I-70, the effectiveness of the overpass structure is dependent on minimizing human disturbance and maintaining a continuous fence line without gaps.

In addition, the fence alignment near the multi-modal trail is generally located in moderate terrain and its close proximity to the highway would facilitate easier installation and maintenance. The placement of the fencing near the treeline on the north side of I-70 is also advantageous because it is generally close to I-70 and is accessible for construction and maintenance activities.

A description of each segment of the wing fencing is provided below.

Town of Vail Side

Fence A:

The Project Team recommends extending the fence from the structure northwest approximately 2/5 mile. The fence extends from the structure parallel to the multi-modal trail to a point where tree cover, the multi-modal trail, and I-70 are all in close proximity. Where the fence ends, there is overlap with the I-70 eastbound concrete barrier, as well as the median concrete barrier and retaining walls. These impediments act as additional barriers for wildlife that would otherwise cross over the highway.

Placing the fence on the south side of the trail, separates it from the I-70 clear zone and provides the remainder of the slope for wildlife foraging (see **Figure 16**). Wildlife use of the slope was indicated by presence of scat and browsed-vegetation (see **Photographs 1**, **2**, and **3**).

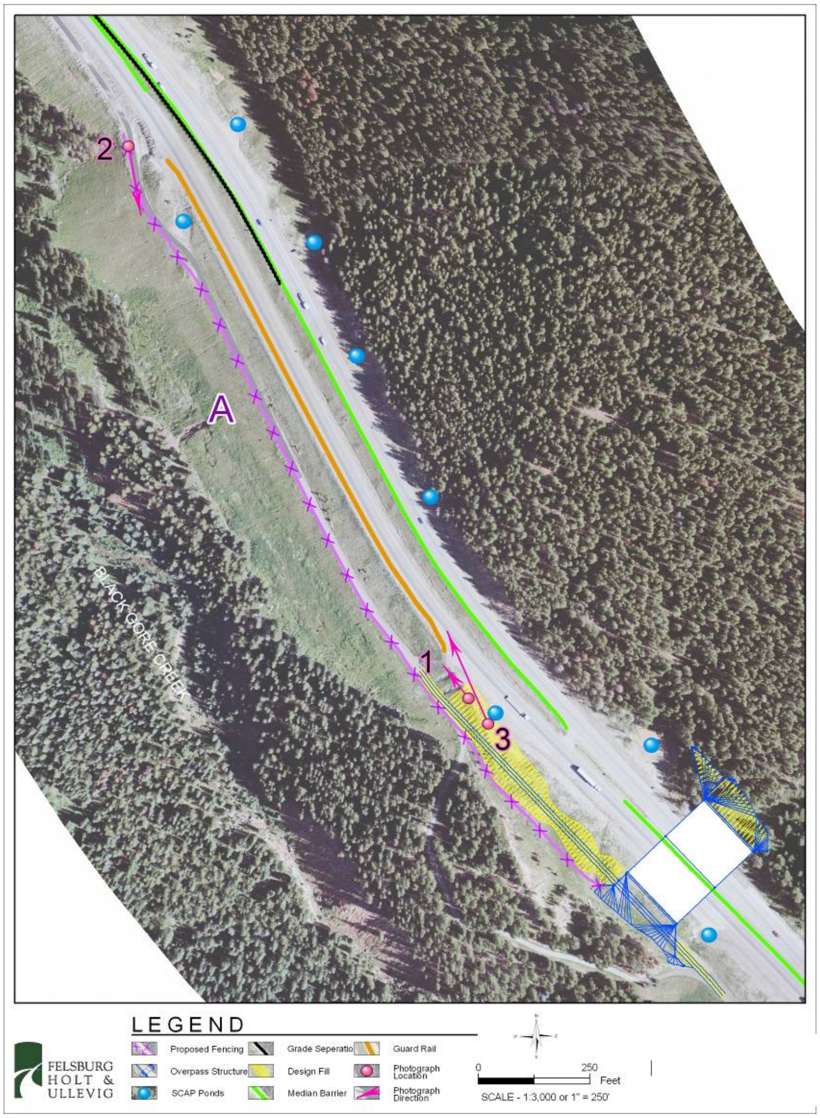


Figure 16 Fence A

Extends off the structure’s retaining wall northwest toward the Town of Vail and ends on top of the cut-slope.

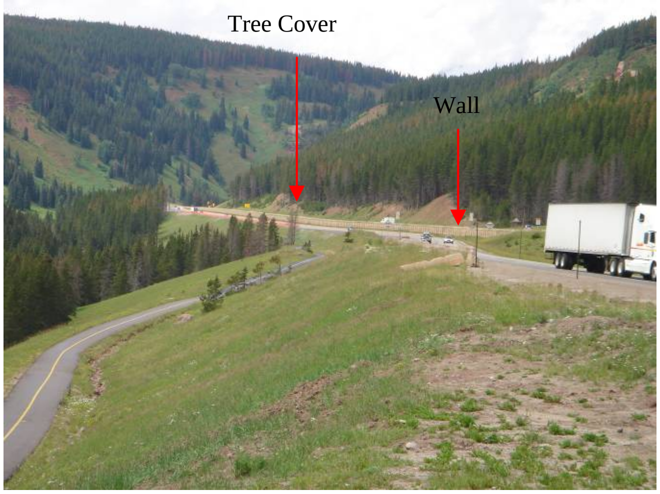


PHOTO 1:
Taken above the multi-modal trail during a bicycle race event. Note the tree cover that approaches the trail on the left. Also, the retaining wall separating the two directions of highway present a barrier. Ending the fence here allows for the inclusion of the meadow area to the left of the trail in the photo.

PHOTO 2:
Taken at end of proposed fence line A, looking toward the bridge structure location. This photo is taken from the end of the fencing length A, near the trees in Photo 1.

PHOTO 3:
Picture near the structure location looking north across the highway. The retaining wall is visible to the right of the orange semi-truck in the background. Note that the water quality pond is being fenced out and that animals will not be attracted to areas near the highway. It is the intended that a water feature will be designed near the structure to serve as a wildlife attractant.

Fence B:

The recommendation is to extend the fence from the structure an estimated 1/5 mile northwest toward the Town of Vail ending on top of the cut-slope (see **Figure 17**). This short distance is due to relatively steep cut/fill slopes near the tree line, overlap with multiple concrete barriers, and parallel wildlife movement.

Placing the fencing at the top-of-cut slope maintains fence stability on otherwise steep, rocky, and unstable cut-slopes. When the fencing is located near the tree line and not on top of the cut-slopes, the fence is located a sufficient distance from the edge of the highway to allow for snow removal activities.

Additionally, during site visits, well established game trails were identified parallel to the highway. In other locations where movement followed several drainages this fence would capture wildlife moving perpendicular to the highway and funnel them to the crossing structure (see **Photographs 4**, **5**, and **6**).

The fencing also restricts wildlife access to several SCAP ponds, which reduces the potential safety issue caused by wildlife congregating at these locations near the highway. The fencing to include SCAP ponds within the highway ROW is also necessary for CDOT maintenance and clearing the ponds of accumulated sediment.

Figure 17 Fence B

Extends off the structure's retaining wall northwest toward the Town of Vail and ends on top of the cut-slope.

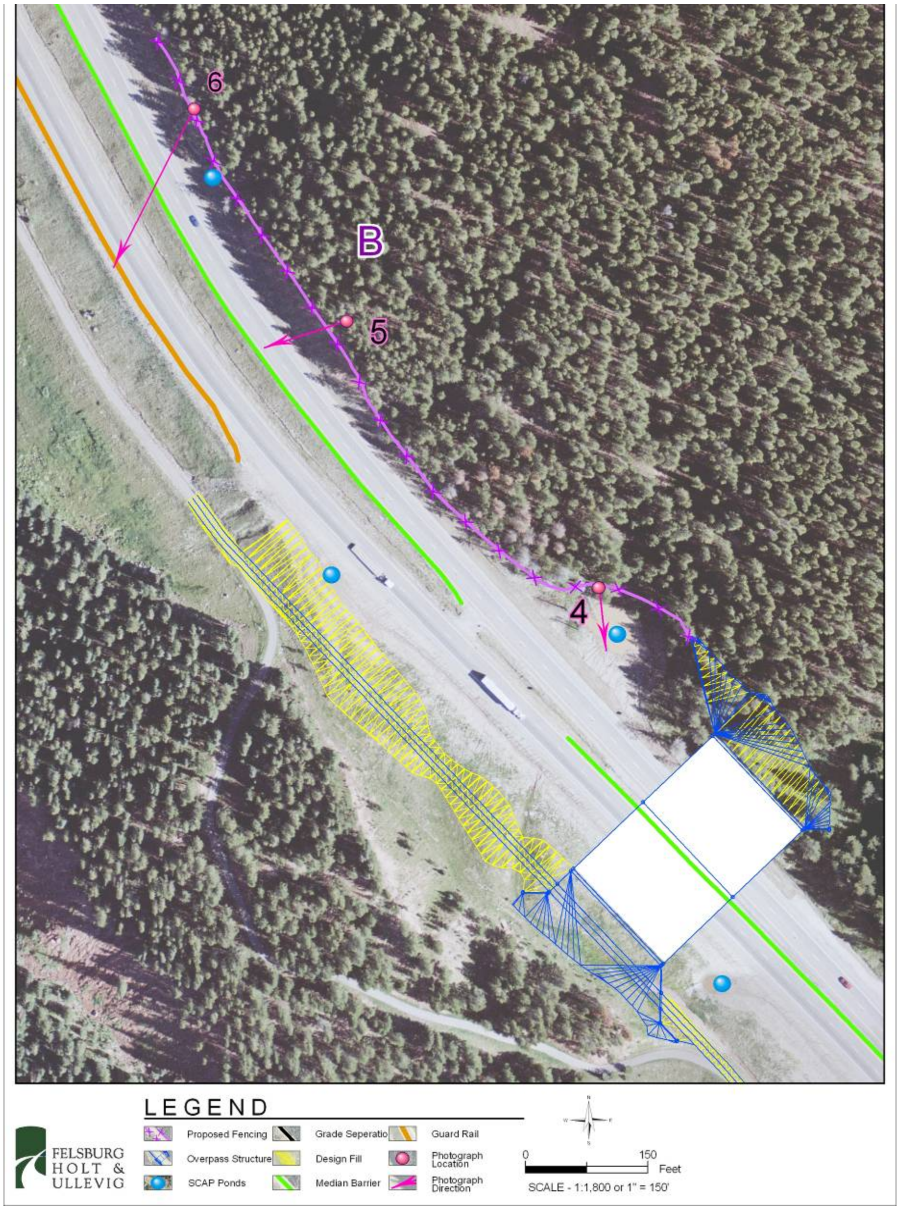


PHOTO 4:

The large SCAP pond northwest of the structure location marked at milepost 187.34. This pond will be fenced to exclude wildlife for maintenance purposes.

PHOTO 5:

Picture taken near the mid-point of Fence B looking west. Note the median guard rail and the eastbound guard rail.

PHOTO 6:

Taken on top of the cut-slope looking southeast near the fence end. Note the steep grade here and the multiple concrete barriers (median and eastbound lanes).

Copper Mountain Side

Fence C:

The Project Team recommends extending the fence from the structure approximately ¼ mile southeast.

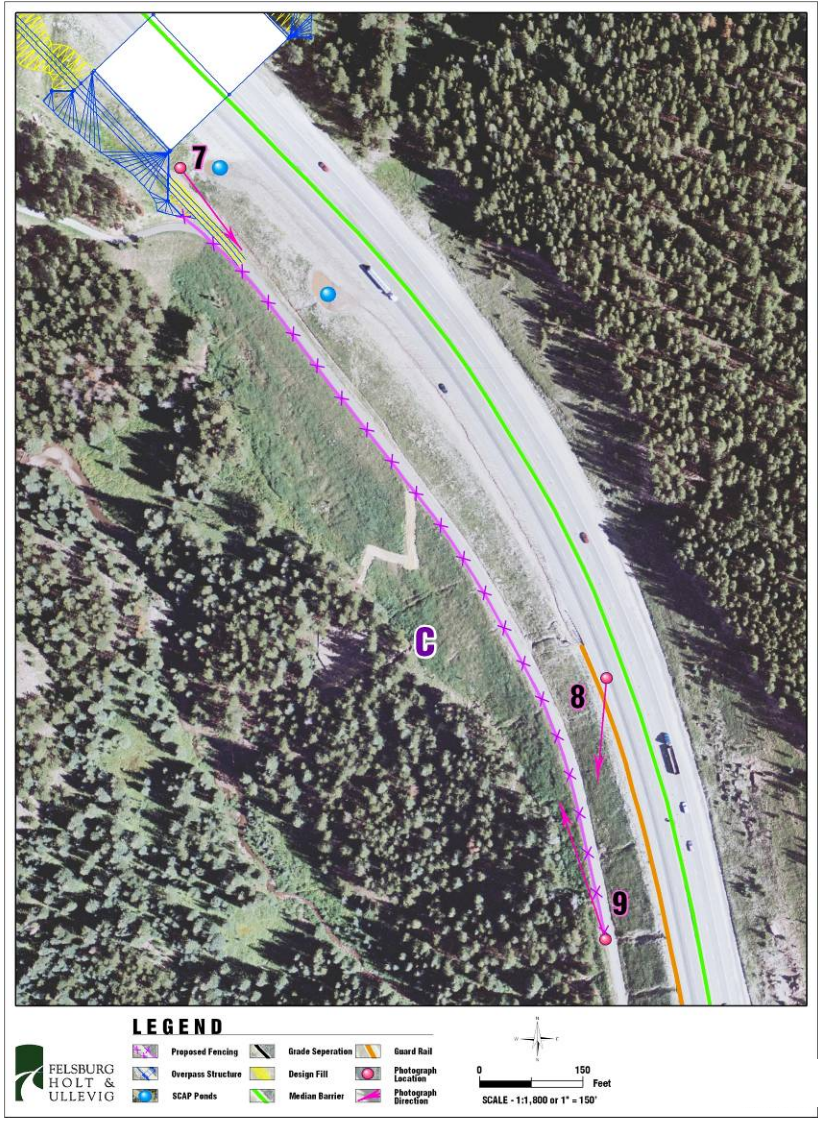
Similar to Fence A, Fence C would be installed south of the multi-modal trail.

This places the fence outside of the I-70 clear zone and provides the remainder of the slope for wildlife foraging. A drainage chute at the end of this fence line could be upgraded with rip-rap to minimize wildlife moving in the fill-slope in between the multi-modal trail and the highway itself (see **Figure 18**).

Photographs 7, **8**, and **9** provide points-of-view from the highway, the multi-modal trail, and from the potential bride structure location.

Figure 18 Fence C

Extend from the structure retaining wall southeast parallel to the multi-modal trail and end next to tree cover and drainage



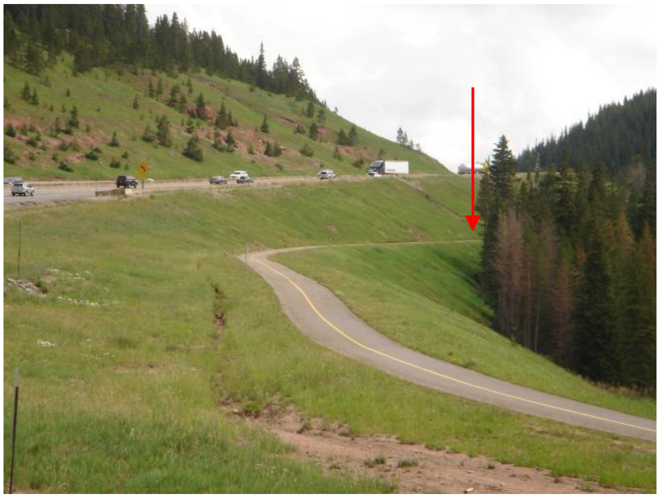


PHOTO 7:
Picture taken near structure location. Note the tree cover on the right and the steep fill-slope on the left of the multi-modal trail. The fence is proposed to end at the eroded culvert/drainage (see arrow).

PHOTO 8:
Taken at the end of Fence C extents. Looking east, this picture shows where the fence would end next to tree cover. The arrow depicts the end of the fencing

PHOTO 9:
Taken from the highway near the fence end. This photo faces southeast. Guard rail and steep slopes discourages animals from crossing the roadway in these sections.

Fence D:

The Project Team recommends extending this fence approximately ¼ mile southeast from the structure and ending on top of a cut-slope near the tree line.

Similar to Fence B, Fence D would be outside of the I-70 clear zone while being more stable on top of the cut-slope (see **Figure 19**). Placing the fencing at the top-of-cut slope maintains fence stability on otherwise steep, rocky, and potentially unstable cut-slopes. Where the fencing is not located on top of the cut-slopes, it will be located a sufficient distance from the edge of the highway to allow for snow removal activities.

Additionally, during site visits, well established game trails were identified parallel to the highway, in other locations where movement followed several drainages this fence would capture wildlife moving perpendicular to the highway and funnel them to the crossing structure (see **Photographs 10**, **11**, and **12**).

Figure 19 Fence D

Extends 0.26 miles from the structure near the tree line and ends on top of the cut-slope where a narrow drainage channel meets the highway.

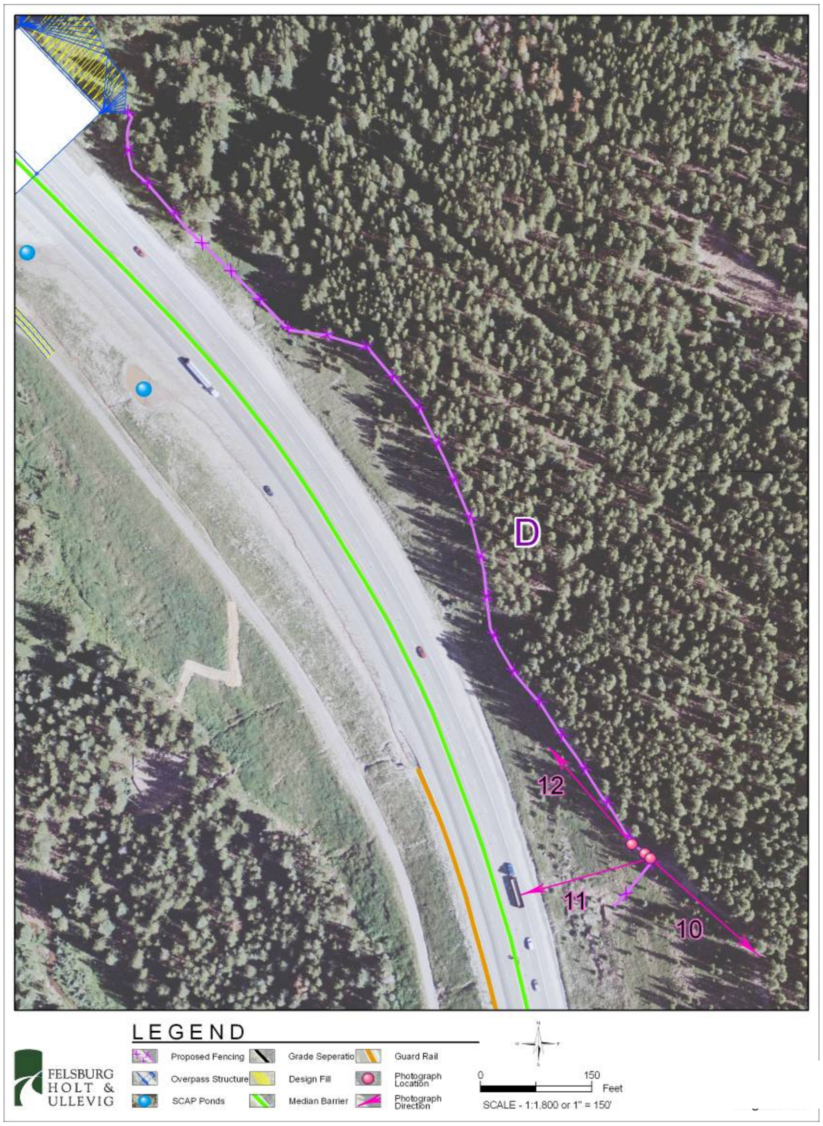


PHOTO 10:
The fence would end mid-photo where the clump of trees are to the left of the center barren ground. The northeast end of the fence would end at the arrow and then move toward the roadway.

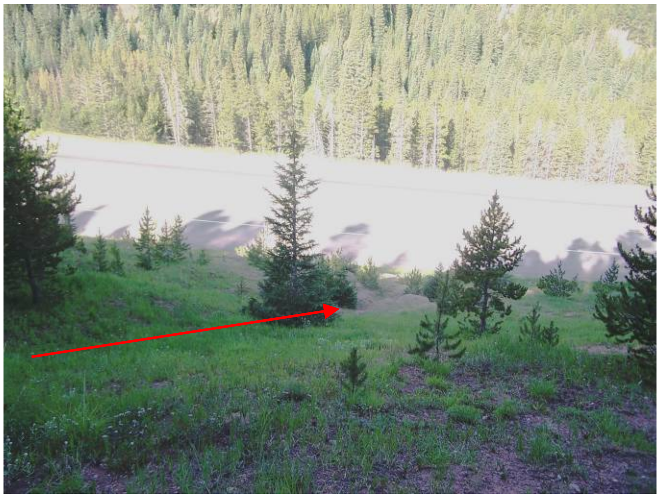


PHOTO 11:
This picture displays a narrow drainage from this slope. There are already several large rocks closer to the highway in the slope. The northeast section of fencing extends down slope to the rip-rap, yet outside of the I-70 clear zone.

PHOTO 12:
Taken near fence end looking northwest toward the structure location. The fence placement would be between the trees and the cut-slope along the noticeable barren ground. There are wildlife movements parallel to the roadway and the fencing in this location attempts to capture this movement and direct the animals toward the structure.

An adaptive management approach to the fencing length and layout is recommended for this project. Pre- and post-construction monitoring and evaluation of the structure will help determine if the wildlife fencing requires adjustments to improve the efficacy of the fencing. The adaptive management strategy for the fencing length and layout for this project should be based upon available pre- and post-construction data such as AVC data, motion-activated photography, track analyses, or other appropriate measures. If the post-construction monitoring data is showing that a large number of animals are moving around the fencing and into the road right-of-way, adjustments to fencing should be made. Further definition of the adaptive management strategies and techniques used on this project will be made during the final design phase.

7.6.3 OTHER FENCING DESIGN ELEMENTS

Other design elements will be considered during later stages of the overpass design, including escape mechanisms, fence type, fence modifications, and fence ends/gaps, and access for maintenance and recreation.

Escape Mechanisms

Escape mechanisms, such as earthen escape ramps or gates, are recommended for the West Vail Pass overpass structure to help wildlife safely exit the ROW if they manage to breach the fence.

Escape ramps have been shown to be over eight times more effective escape mechanisms than one-way gates (Bissonnett, Hammer, & Haynes McCoy, 2004; Bissonette & Hammer, 2000). Escape ramps also require less maintenance, and facilitate a more natural exit from the ROW than a metal gate (Bissonnett et al., 2004; Bissonette & Hammer, 2000). If escape ramps are used, determining the number of escape ramps will be dependent on the length of fencing that is selected. In general, it is recommended that escape ramps are placed every ¼ mile from fence ends and ¼ mile to ½ mile throughout the fencing limits (Bissonette & Hammer, 2000).

Fence Ends

During later stages of design, fence ends will be assessed to determine if special design requirements are necessary to minimize access to the right-of-way at these locations.

Fence Type/Modifications

Standard CDOT game fencing is typically used in conjunction with wildlife crossing structures in Colorado. This fencing consists of page-wire with wooden posts, and is 8 feet tall. During later stages of design, the need for potential modifications to the standard CDOT game fencing will be discussed and engineering solutions will be determined. Potential modifications include: height, mesh durability, and mesh size.

Fence Access (Maintenance/Recreation)

The need for recreational and maintenance access gates will also be determined during later stages of design.

8.0 CONCEPTUAL DESIGN

Using the design criteria developed and discussed in **Section 7.0**, the Project Team developed a conceptual design for the wildlife overpass structure. An additional consideration for the conceptual design was not precluding any of the PEIS design alternatives, which may include climbing/deceleration lanes in each direction and a transit component. The span of the wildlife bridge was designed to accommodate future roadway widening (six-lanes, including inside and outside shoulders), clear zones, as well as a transit envelope.

The conceptual design is presented in **Appendix B**. A notable feature of the design is the relocation of the multi-modal bicycle path on the south side of I-70. The current alignment of the trail would be near the toe-of-slope of the south side landing of the overpass structure. To reduce the human and wildlife interactions, the trail was redesigned to go under the fill slope on the south side of the overpass structure. A box culvert would be placed in the fill to accommodate the multi-modal trail.

Additional site topographic survey and geotechnical investigation, as discussed in the next section may result in adjustments and alterations in the conceptual design. These may include the type of foundation for the structure and walls.

To develop the conceptual bridge layout and cost estimate, the following design assumptions were established:

- A 100 pounds per square foot (psf) snow live load was applied to conduct a preliminary girder design check. A more detailed snow analysis for the bridge is planned in the next phase.
- A 75 psf dead load for various landscaping elements such as trees, boulders, logs, etc. was assumed.
- A density of 150 pounds per cubic foot (pcf) was assumed for the soil on the bridge to account for a saturated fill condition.
- The approaches on both sides of the crossing structure were graded at a 3:1 slope. This was sufficient to provide slope stability for the structure while still maintaining a slope that wildlife could traverse.
- An underdrain system beneath the fill on the bridge was assumed to consist of a series of perforated 4-inch diameter PVC pipes that would drain the bridge deck towards the southwest corner of the structure. This drainage would supply water for a new pond proposed south of the bridge to attract wildlife to the area.
- The bridge was assumed to have two 120’-0” spans and tall wall abutments to allow for the most flexibility for accommodating future lane and transit corridor additions under the bridge. Future widening is anticipated, but the final configuration is unknown. This section of I-70 has also been used for depositing snow removed from other segments of the interstate as well as the Town of Vail. The tall wall abutments will maintain a potential snow storage area beneath the bridge, but off the interstate.
- A minimum clearance of 18’ was established over I-70 to meet and exceed CDOT and AASHTO requirements. The minimum clearance occurs at the median line along eastbound I-70 along the east side of the bridge. The additional clearance was to ensure that oversized vehicles could use the interstate and any potential transit needs.
- Three wall pier sections were assumed for the conceptual layout, which will be isolated by expansion joints in the cap. The solid wall piers will benefit the snow roadway snow removal effort along the median, minimizing gaps where snow could potentially collect.
- An 8” concrete deck, resembling a typical highway bridge deck was assumed, which will be supported on precast/prestressed BT72 concrete girders spaced approximately 5’-8” on-center. Steel plate girders could be considered as an alternate superstructure system, but it is likely a steel system would be much more costly than the BT72 alternative. Post-tensioned alternatives for the bridge construction were not considered in the conceptual design due to high cost and construction staging concerns at this site.
- Concrete barriers along each end of the bridge were set 3’-0” above the finished grade of the fill on the bridge to provide some noise attenuation. A 5’-0” high fence was assumed on the concrete to provide an overall barrier height of 8’-0”. The fencing was assumed to be similar to CDOT’s standard deer fencing, which has mesh openings large enough to allow snow to pass through, and minimize drifting on the bridge.
- The walls off each corner of the bridge were assumed to be mechanically stabilized earth (MSE) walls, which are the most economical wall type for this site. Since the construction will be mostly above existing grade, the MSE construction will be the simplest approach. The MSE wall faces can be finished in a variety of ways that will meet the aesthetic standards for the project. A stone-faced finish was assumed for the conceptual layout and cost estimating purposes.

These assumptions were made prior to the site data collection effort conducted above, and have not been modified since the field work was completed.

The re-aligned bicycle trail was laid out to fit the proposed box culvert at the south end of the bridge (set at a 2% longitudinal grade), and continues at a maximum grade of 10% west of the bridge. The 10% grade matches the existing trail grade just west of the re-aligned trail segment. The trail profile has been provided with the conceptual bridge exhibits.

The remaining funding from the Federal Grant will allow the Project Team to continue the design effort.

9.0 OTHER DESIGN ITEMS

After the site for the overpass structure was determined, additional site data collection needed for detailed design was initiated. A detailed topographic survey was completed for use in the design process. The survey focused on the areas surrounding the mile marker 187.4. A geotechnical investigation was completed at sites surrounding major supporting structures for the bridge (i.e., abutments and piers). This information is used to determine the appropriate type of foundation for the bridge.

Bedrock was not encountered during the geotechnical investigation. Often, bridge foundations extend into bedrock to provide a definitive footing. The geotechnical engineer determined that the site at 187.4 is on an ancient rockslide. This creates the relatively flat area at 187.4, which resulted in many of the preferable characteristic for the placement of the wildlife crossing structure. Additional discussions and consideration of alternative foundations are required to finalize the design. The geotechnical report is presented in **Appendix C**.

Snow loading and drifting at the proposed bridge location will be an important element of the bridge design, and will require further investigation. Snow consultants were contacted to provide snow loading design recommendations for the site, but no work was executed. The icing potential of I-70 under the structure was also to be investigated as part of this effort, with recommendations developed for potential warning systems where icing potential may be present.

10.0 REFERENCES

Barnum, S. A. (2003). Identifying the best locations along highways to provide safe crossing opportunities for wildlife: A handbook for highway planners and designers. Prepared for the Colorado Department of Transportation. Report No. CDOT-DTD-UCD_2003-9.

Bastings, P. (2007). Overview of Highway 93 wildlife crossings, Montana. Presentation at the Interstate 70 Wildlife Crossing Workshop, Utah Department of Transportation, USDA Forest Service, Richfield, Utah.

Bissonette, J. A. & Hammer, M.L. (2000). Effectiveness of earthen return ramps in reducing big game highway mortality in Utah, Final report. Report no. UT-01.09, Utah Department of Transportation, Salt Lake City, Utah.

Bissonette, J. A., Hammer, M.L., & Haynes McCoy, N. (2004). Getting deer off of the road: A better way. USGS Utah Cooperative Fish and Wildlife Research Unit, College of Natural Resources, Utah State University, Logan UT.

Clevenger, A. P. (2002). Mitigation for impacts to roads on wildlife. In *Proceedings of the International Conference on Ecology and Transportation* (pp. 85-91), Keystone, CO, Raleigh, NC: Center for Transportation and the Environment, North Carolina State University. March.

Clevenger, A. P., B. Chruszcz, and K. Gunson. (2001). Drainage culverts as habitat linkages and factors affecting passage by mammals. In *Journal of Applied Ecology* 38,1340-1349.

Clevenger, A. P., Chruszcz, B., Gunson, K., & Wierzchowski, J. (2002). *Roads and wildlife in the Canadian Rocky mountain parks - Movements, mortality and mitigation*. Banff, Alta.: Parks Canada. Retrieved December 1, 2005, from http://www.praxis.ca/banfftwinning/pdfs/ClevengerReport2002.PDF

Clevenger, A.P., & Waltho N. (2000). Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology* 14 (1), 47-56.

Clevenger, A.P., & Waltho N. (2005). Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. *Biological Conservation,* 121, 453-464.

Crooks, K., Haas, C., Baruch-Mordo, S., Middledorf, K., Magle, S., Shenk, T., Wilson, K., and Theobald D. Colorado State University. (2008). Draft Roads and Connectivity in Colorado: Animal-Vehicle Collisions, Wildlife Mitigation Structures, and Lynx-Roadway Interactions. Prepared for: Colorado Department of Transportation. Report No. CDOT-2008-4.

Foresman, K. (2001). Monitoring Animal Use of Modified Drainage Culverts on the South Lolo Project. FHWA/MT-01-004/8117-15. Final Report. Prepared for the State of Montana in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

Forman, R. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C.

D., Dale, V. H., et al. (2003). Mitigation for wildlife. In *Road ecology:*

Science and solutions (pp. 139-167). Washington, D.C.: Island Press.

Gagnon, J. W., Dodd, N.L., Schweinsburg, R.E., & Manzo, A.L. (2006). Use of video surveillance to assess wildlife behavior and use of wildlife underpasses in Arizona. In Proceedings of the 2005 International Conference on Ecology and Transportation, edited by C. Leroy

Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Haas, C.D. (2000). Distribution, relative abundance, and roadway underpass responses of carnivores throughout the Puente-Chino Hills. Master Thesis, California State Polytechnic University, Pomona, California.

Hardy, A., Fuller, J., Huijser, M., Kociolek, A., & Evans, M. (2007). Evaluation of wildlife crossing structures and fencing on US Highway 93 Evaro to Polson phase I: Preconstruction data collection and finalization of evaluation plan. Western Transportation Institute, Montana State University. Prepared for: The State of Montana Department of Transportation, in cooperation with the U.S. Department of Transportation, Federal Highway Administration. FHWA/MT-06-008/1744-1

Jaeger, J.A.G & Fahrig, L. (2004). Effects of road fencing on population persistence. *Conservation Biology.* 18 (6), 1651-1657.

Kratz, Andrew. Personal Interview. 29 April 2008.

Leeson, Bruce. Personal Interview. 30 April 2008.

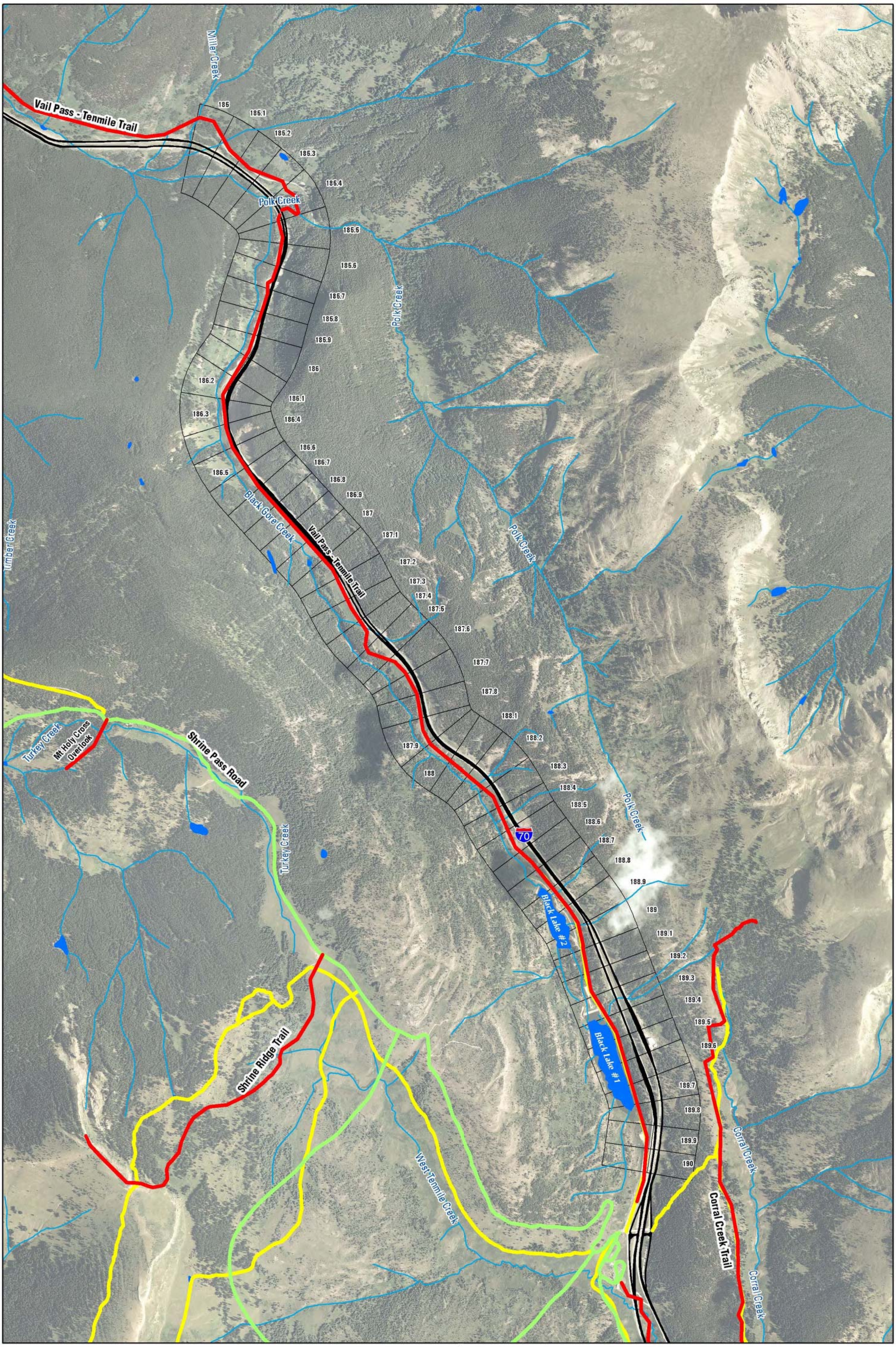
Lyren L.M. and K. R. Crooks. (2001). Factors influencing the movement, spatial patterns, and wildlife underpass use of coyotes and bobcats along State Route 71 in Southern California. IN: Proceedings of the 2001 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: p. 490.

Ruediger, W.C, Wall K. & Wall R. (2006). Effects of highways on elk (Cervus elaphus) habitat in the Western United States and proposed mitigation approaches. IN: Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC, 269-278.

Southern Rockies Ecosystem Project, U.S. Department of Transportation, Colorado Department of Transportation, Colorado State University, and The Nature Conservancy. (2005). Linking Colorado’s Landscapes: A Statewide Assessment of Wildlife Linkages Phase I Report. March.

U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA), and Colorado Department of Transportation (CDOT). (2004). I-70 Mountain Corridor Draft Programmatic Environmental Impact Statement/Section 4(f) Evaluation. December.

Appendix A
Materials Presented at Wildlife Panel Meetings



Legend

🟥	White River National Forest Trails
🟩	Vail Pass Designated Snowmobile Trails
🟨	Vail Pass Recreation Cross Country Trails
~	Streams

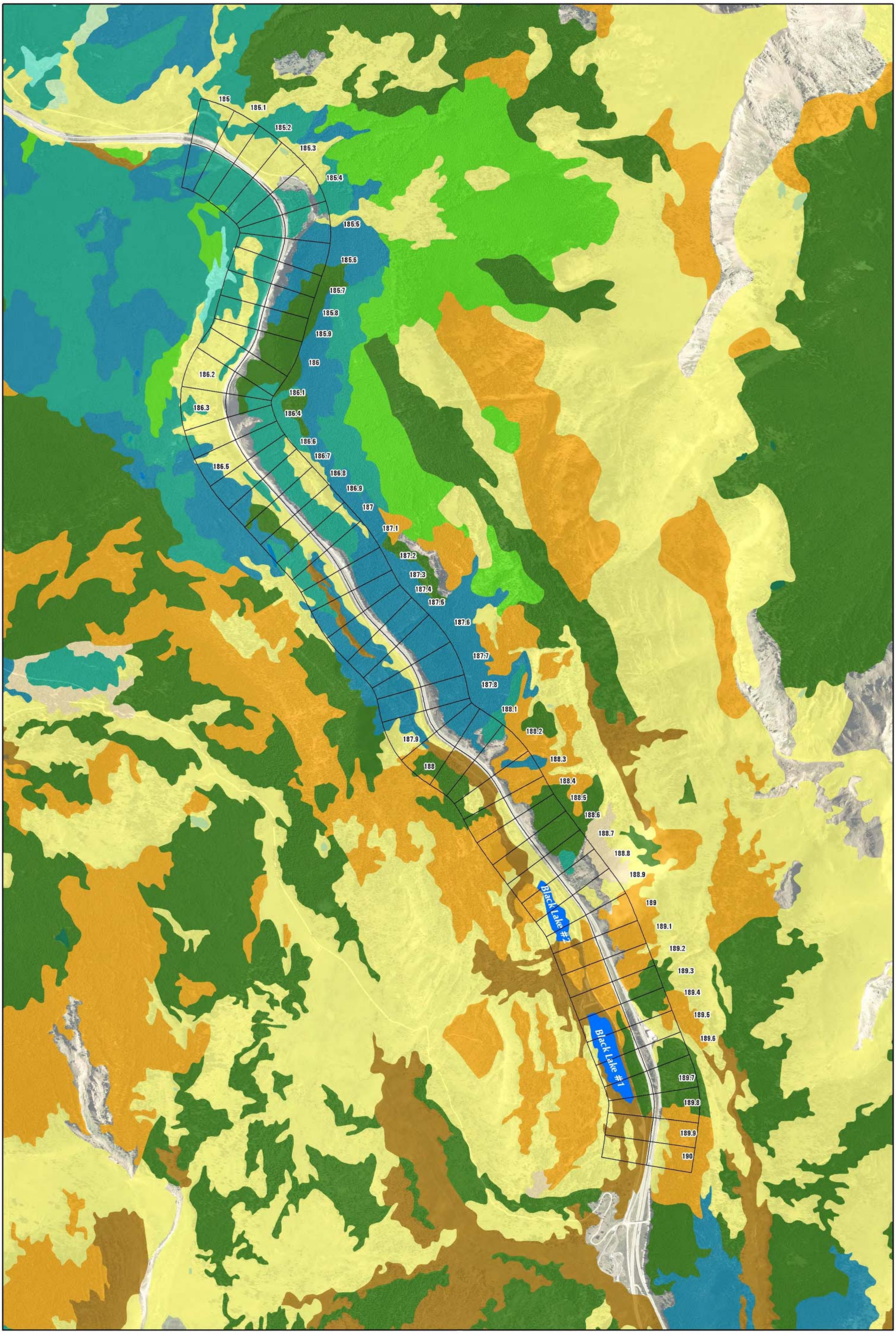
▲ NORTH

2,000 0 2,000 Feet

SCALE - 1:24,000 or 1" = 2,000'

West Vail Pass Habitat Linkage

White River National Forest Trails



LEGEND

🟩	aspen	🟩	lodgepole pine mixed
🟩	aspen with conifer	🟪	shrub
🟧	engelmann spruce	🟩	spruce/fir
🟨	engelmann spruce mixed	🟦	spruce/fir mixed
🟨	grass/forb	☐	water
🟩	lodgepole pine	🟫	willow

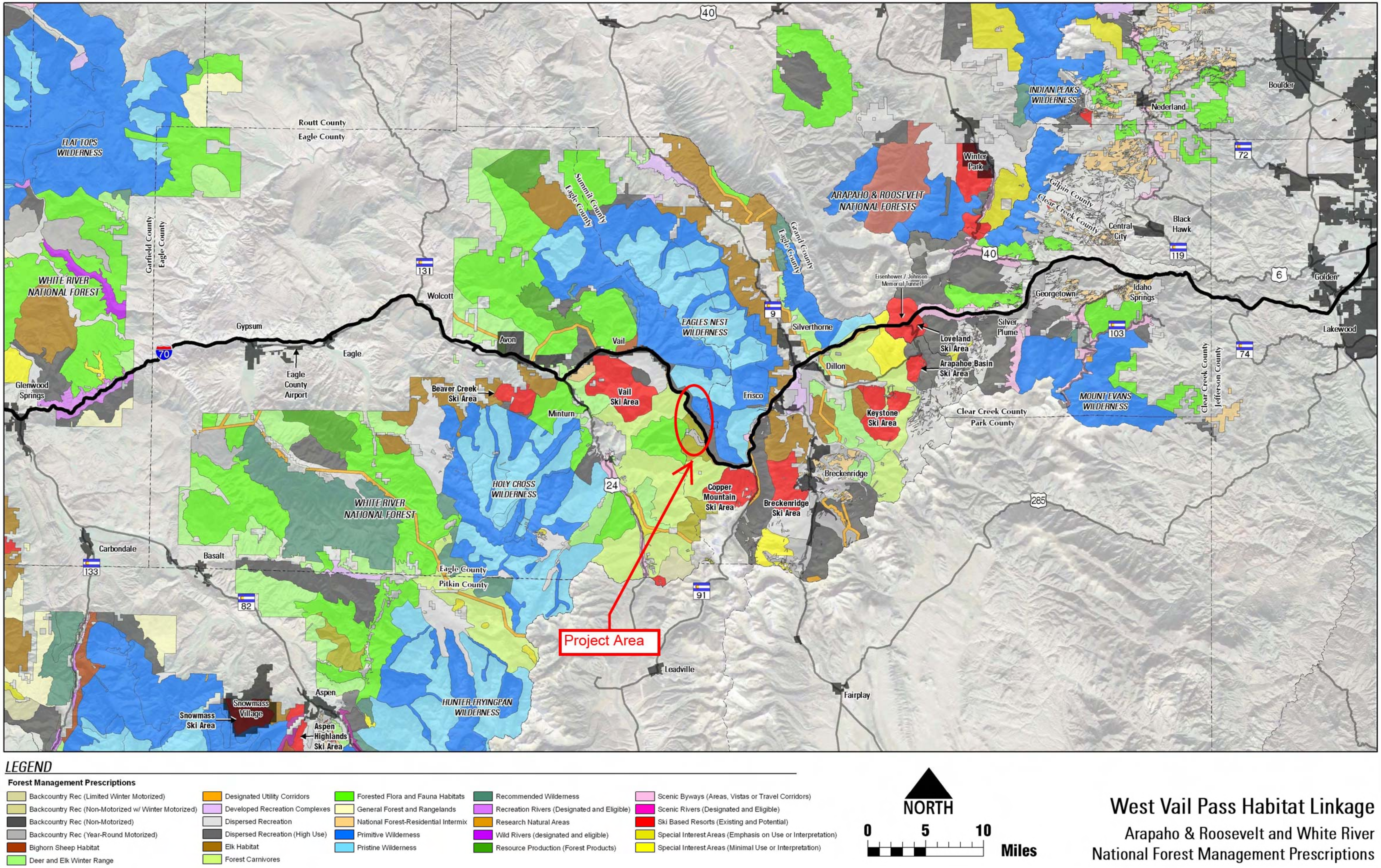
NORTH

2,000 0 2,000 Feet

SCALE - 1:24,000 or 1" = 2,000'

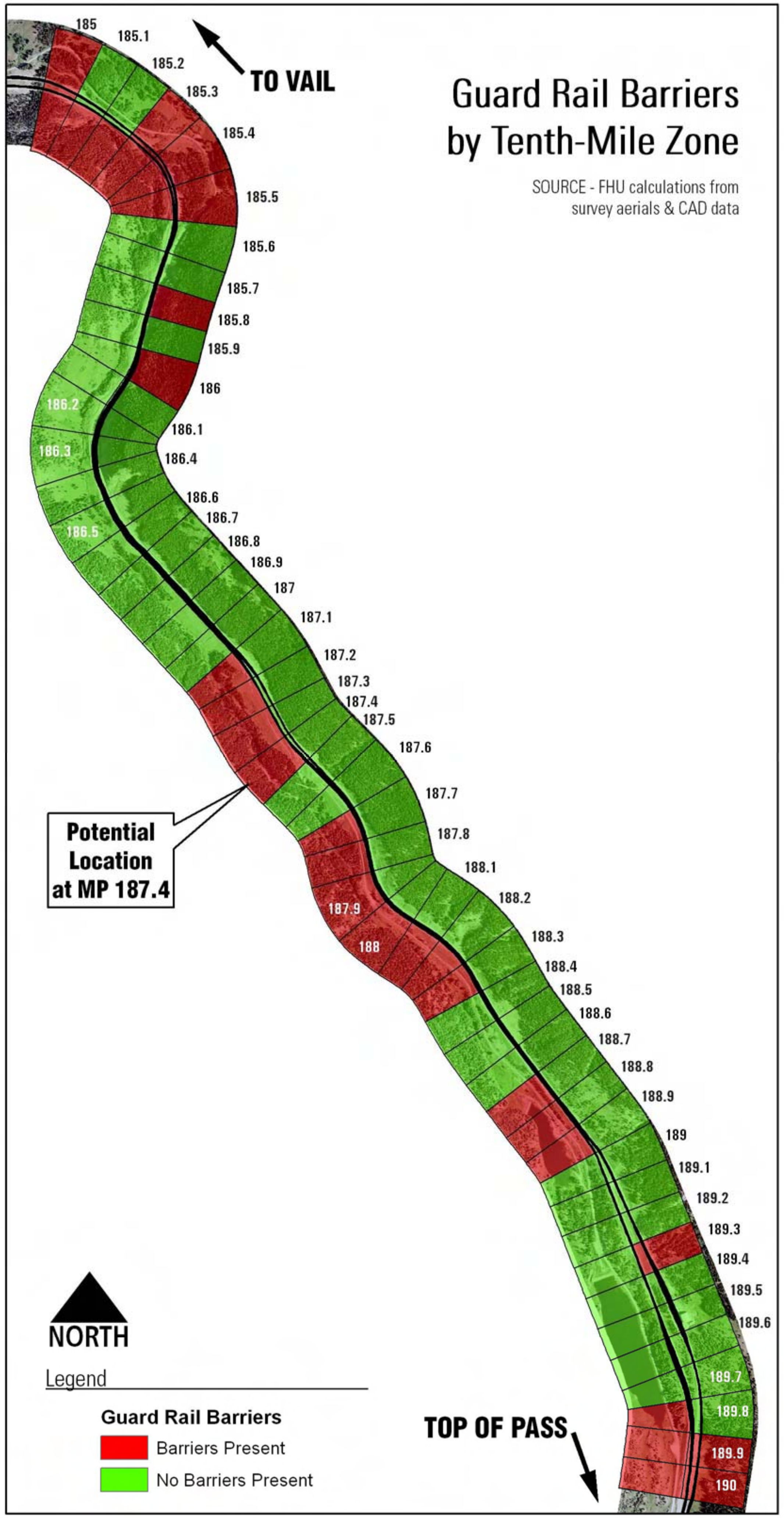
West Vail Pass Habitat Linkage

White River National Forest
Vegetation Classification



West Vail Pass Habitat Linkage

Arapaho & Roosevelt and White River
National Forest Management Prescriptions



Guard Rail Barriers by Tenth-Mile Zone

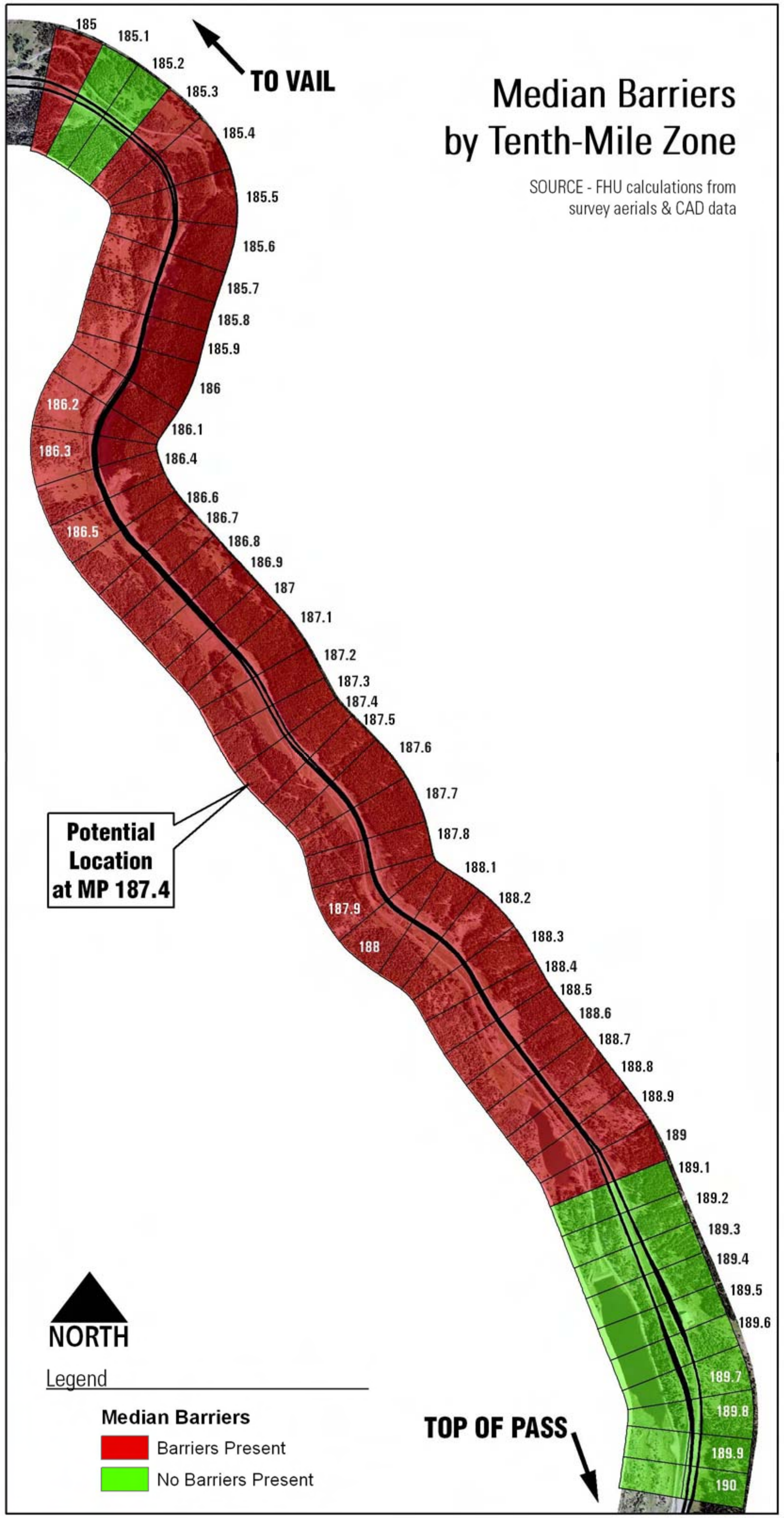
SOURCE - FHU calculations from survey aerials & CAD data

Legend

Guard Rail Barriers

🟥 Barriers Present

🟩 No Barriers Present



Median Barriers by Tenth-Mile Zone

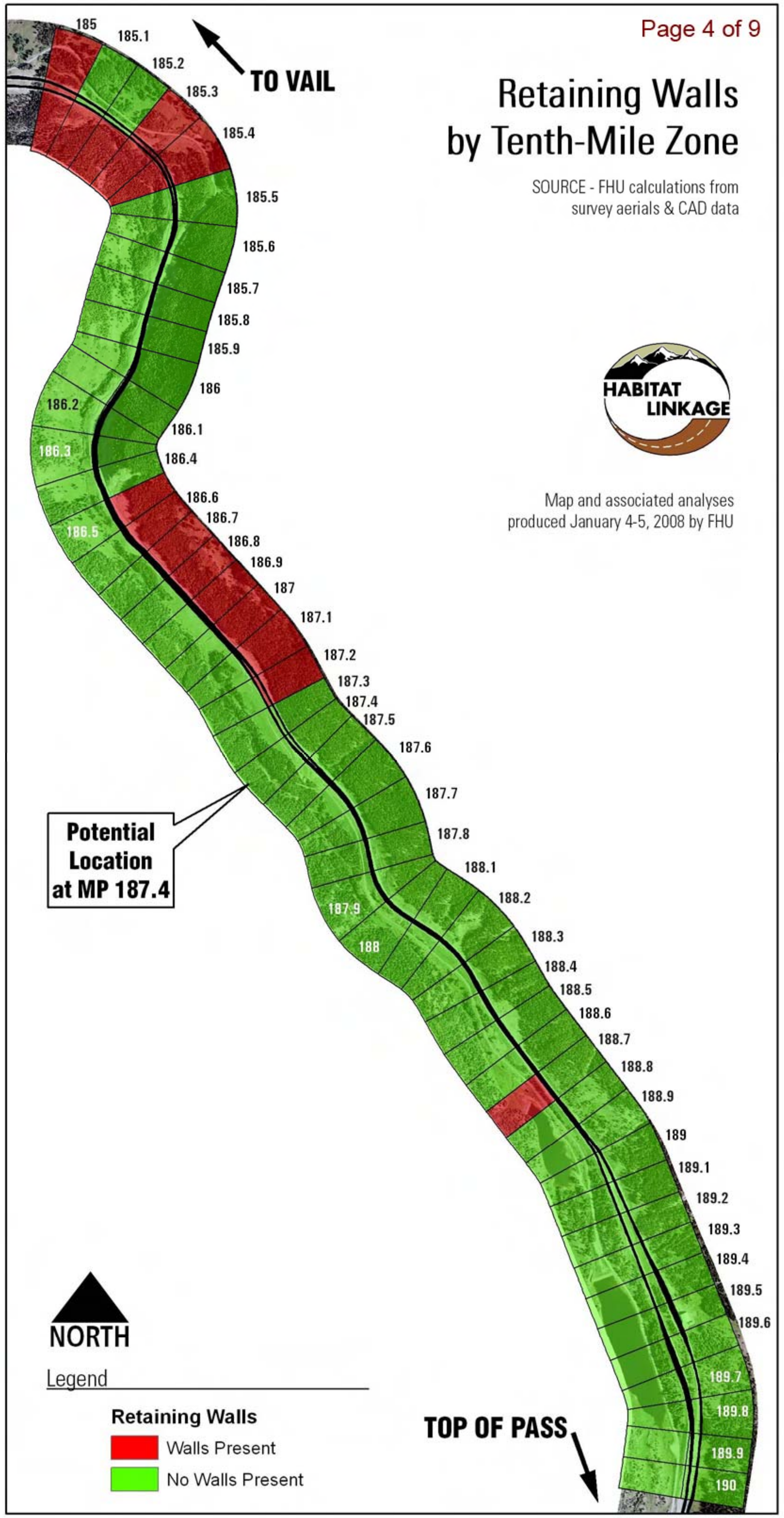
SOURCE - FHU calculations from survey aerials & CAD data

Legend

Median Barriers

🟥 Barriers Present

🟩 No Barriers Present



Retaining Walls by Tenth-Mile Zone

SOURCE - FHU calculations from survey aerials & CAD data

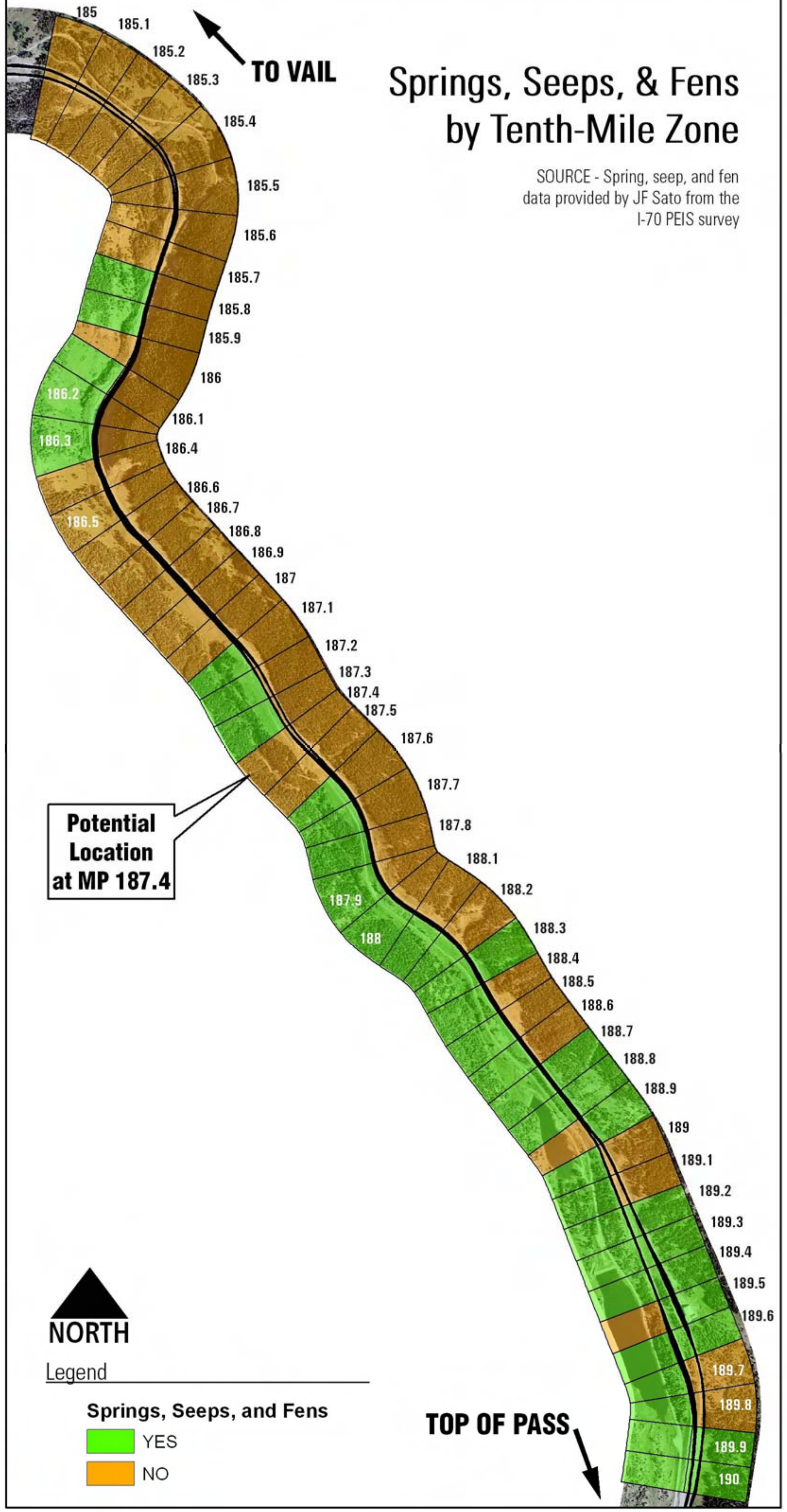
Map and associated analyses produced January 4-5, 2008 by FHU

Legend

Retaining Walls

🟥 Walls Present

🟩 No Walls Present



Springs, Seeps, & Fens by Tenth-Mile Zone

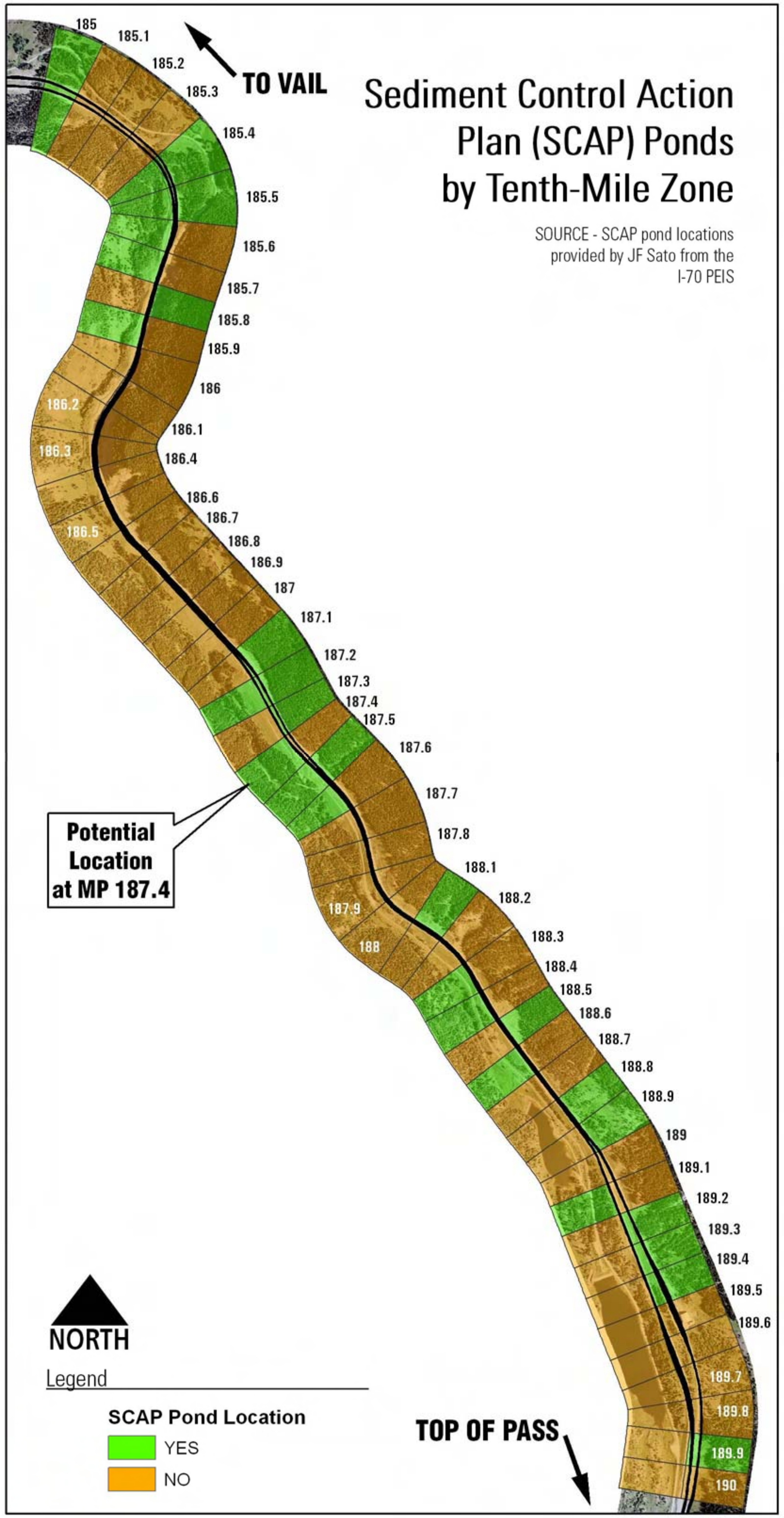
SOURCE - Spring, seep, and fen data provided by JF Sato from the I-70 PEIS survey

Legend

Springs, Seeps, and Fens

🟩 YES

🟧 NO



Sediment Control Action Plan (SCAP) Ponds by Tenth-Mile Zone

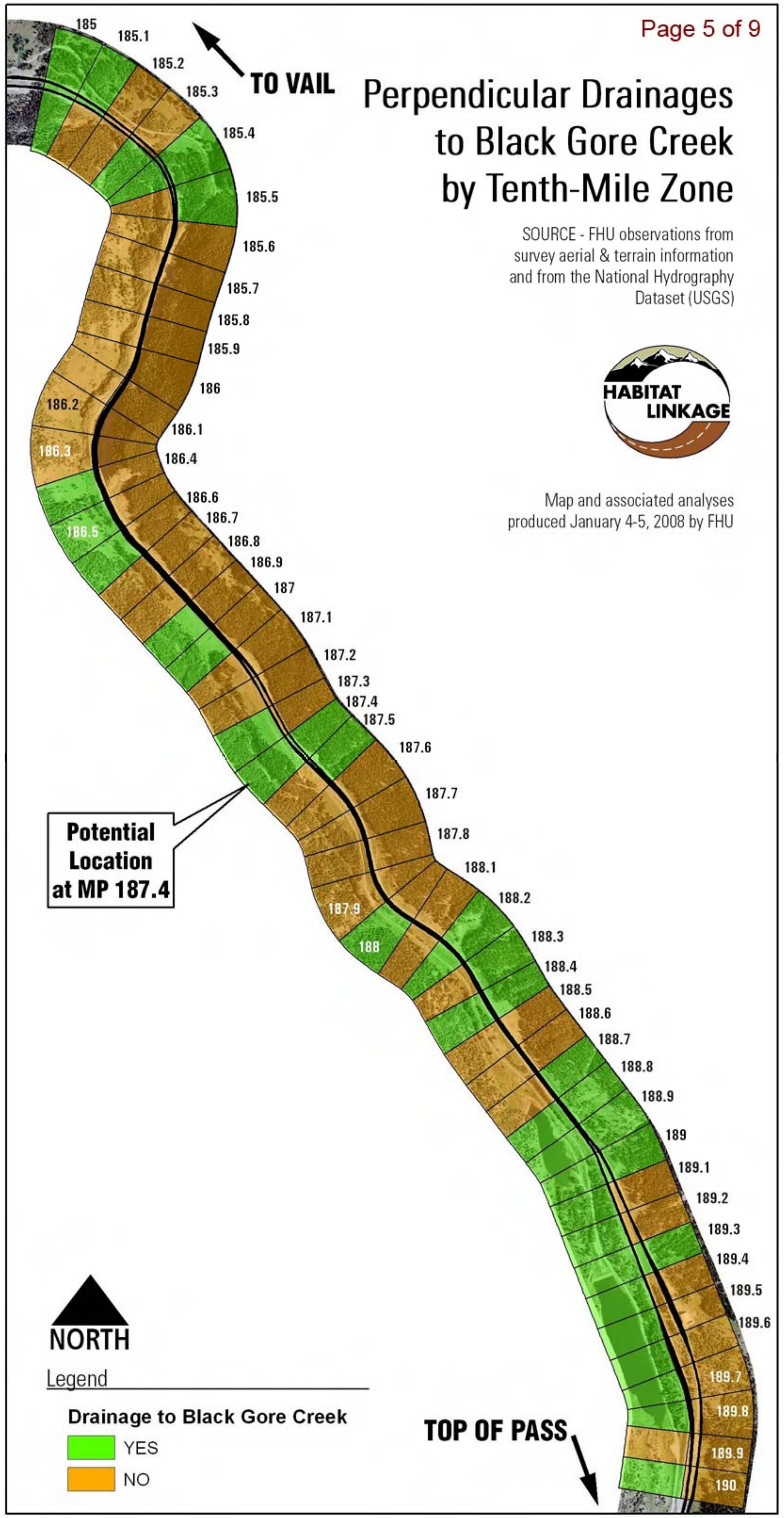
SOURCE - SCAP pond locations provided by JF Sato from the I-70 PEIS

Legend

SCAP Pond Location

🟩 YES

🟧 NO



Perpendicular Drainages to Black Gore Creek by Tenth-Mile Zone

SOURCE - FHU observations from survey aerial & terrain information and from the National Hydrography Dataset (USGS)

HABITAT LINKAGE

Map and associated analyses produced January 4-5, 2008 by FHU

Legend

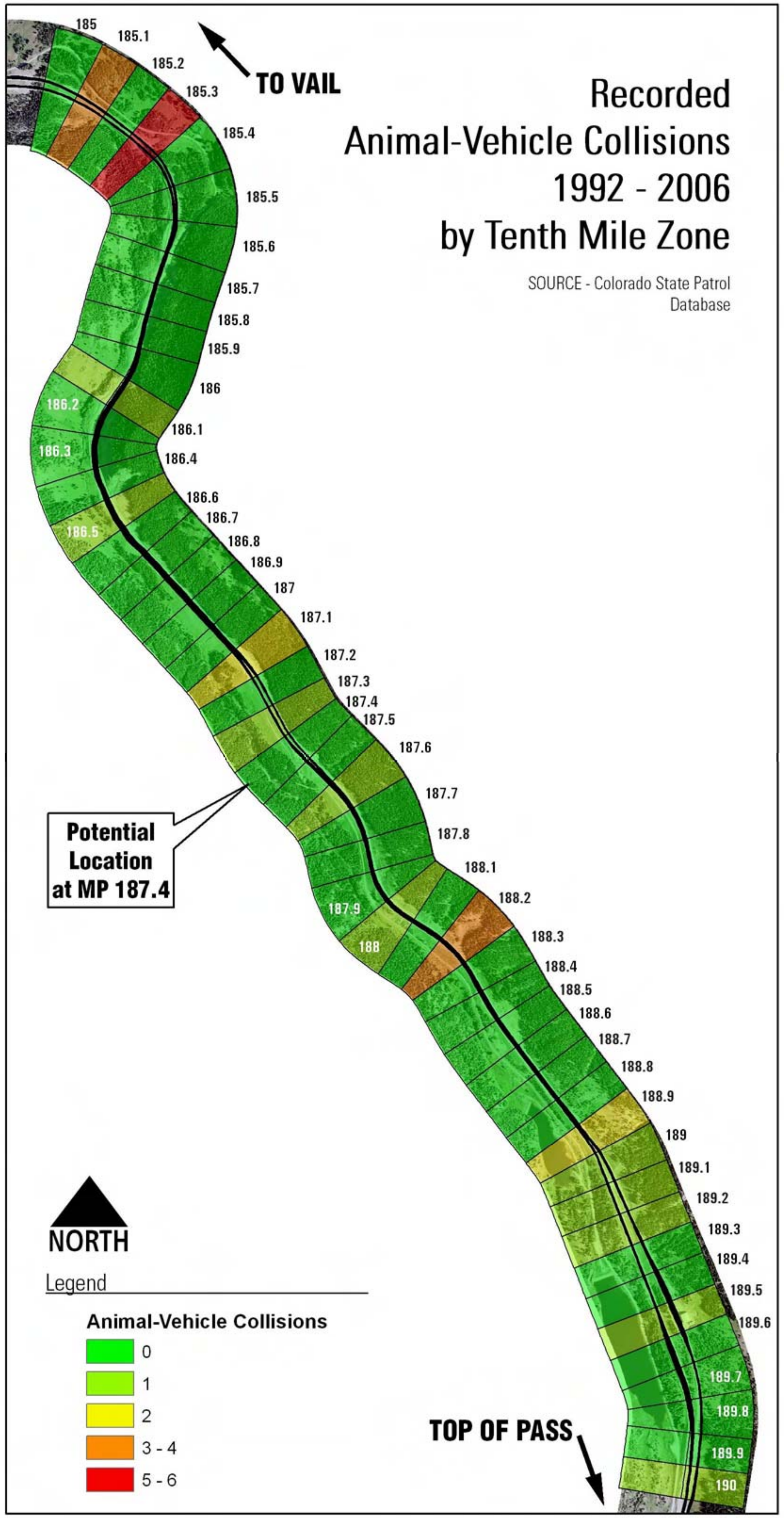
Drainage to Black Gore Creek

🟩 YES

🟧 NO

Recorded Animal-Vehicle Collisions 1992 - 2006 by Tenth Mile Zone

SOURCE - Colorado State Patrol Database



Potential Location at MP 187.4

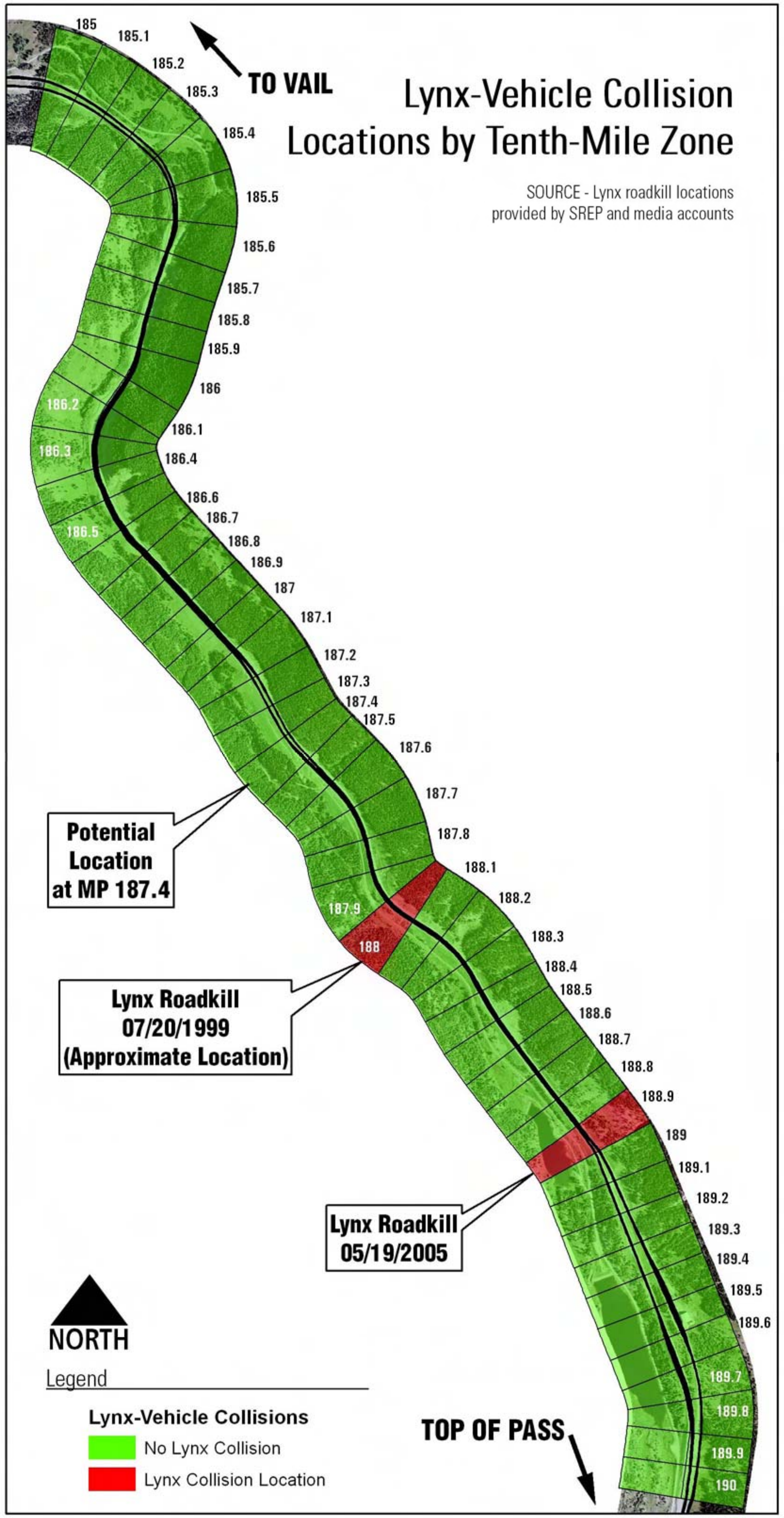
Legend

Animal-Vehicle Collisions

🟩 0
🟩 1
🟨 2
🟧 3 - 4
🟥 5 - 6

Lynx-Vehicle Collision Locations by Tenth-Mile Zone

SOURCE - Lynx roadkill locations provided by SREP and media accounts



Potential Location at MP 187.4

Lynx Roadkill 07/20/1999 (Approximate Location)

Lynx Roadkill 05/19/2005

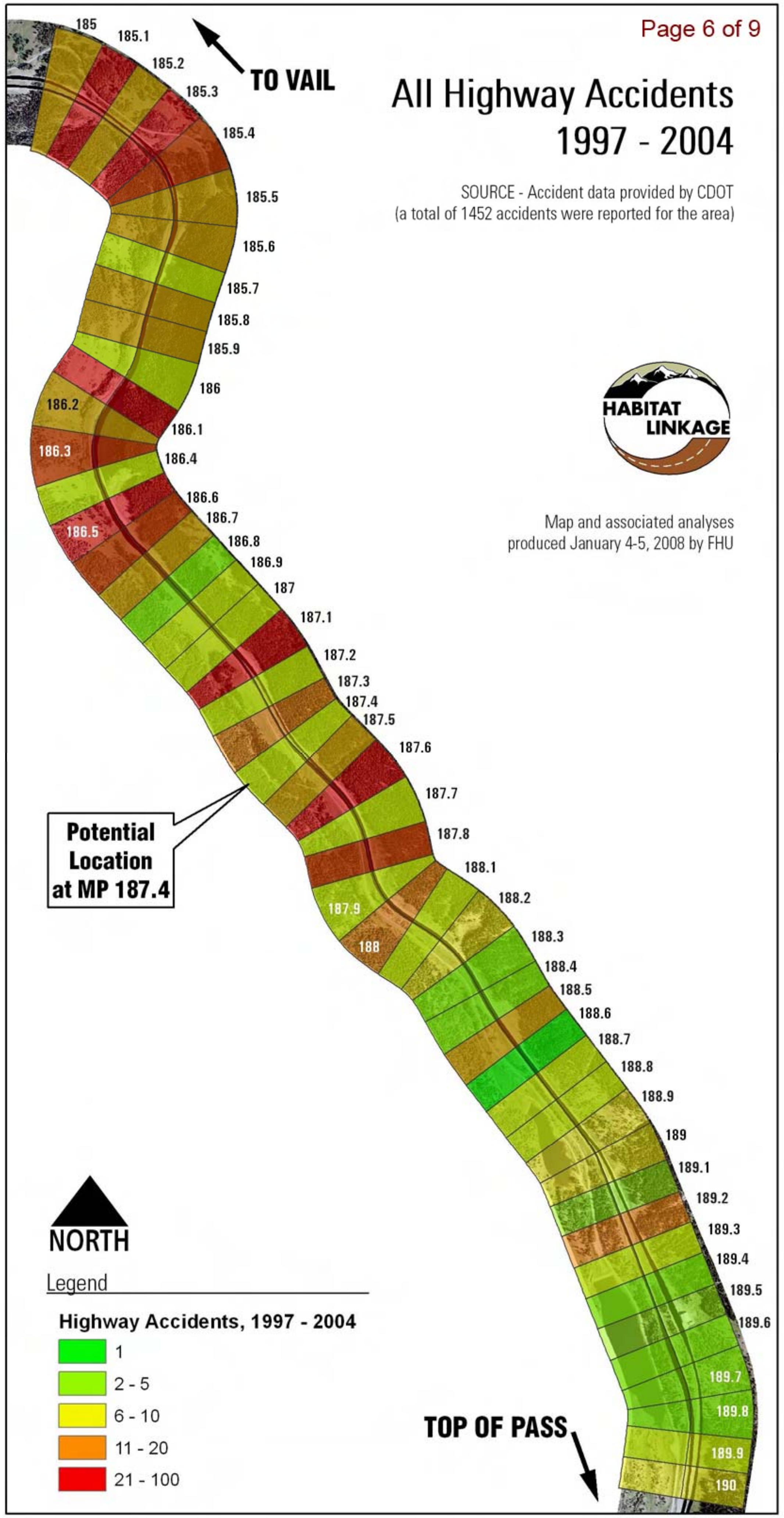
Legend

Lynx-Vehicle Collisions

🟩 No Lynx Collision
🟥 Lynx Collision Location

All Highway Accidents 1997 - 2004

SOURCE - Accident data provided by CDOT (a total of 1452 accidents were reported for the area)



Map and associated analyses produced January 4-5, 2008 by FHU

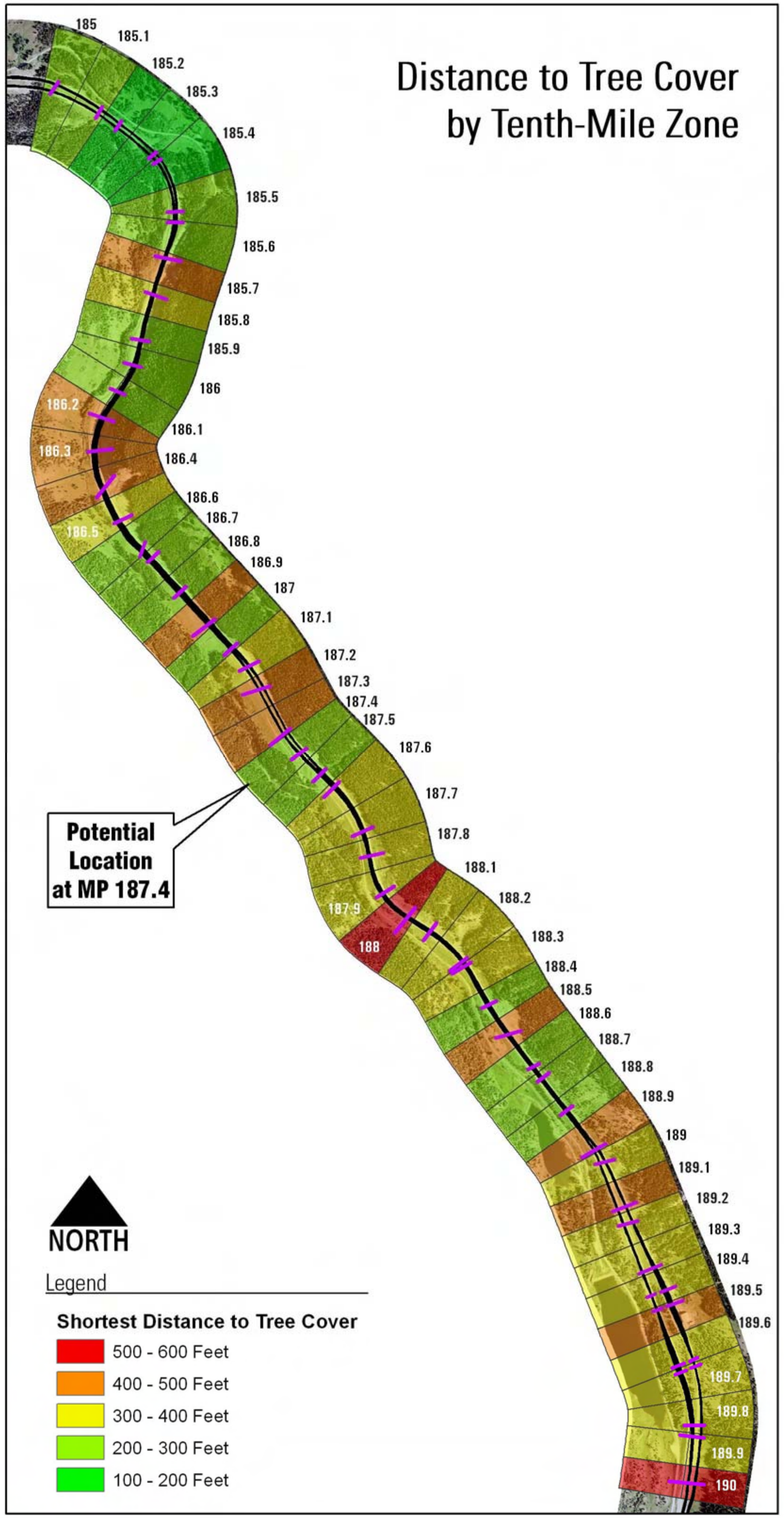
Potential Location at MP 187.4

Legend

Highway Accidents, 1997 - 2004

🟩 1
🟩 2 - 5
🟨 6 - 10
🟧 11 - 20
🟥 21 - 100

Distance to Tree Cover by Tenth-Mile Zone

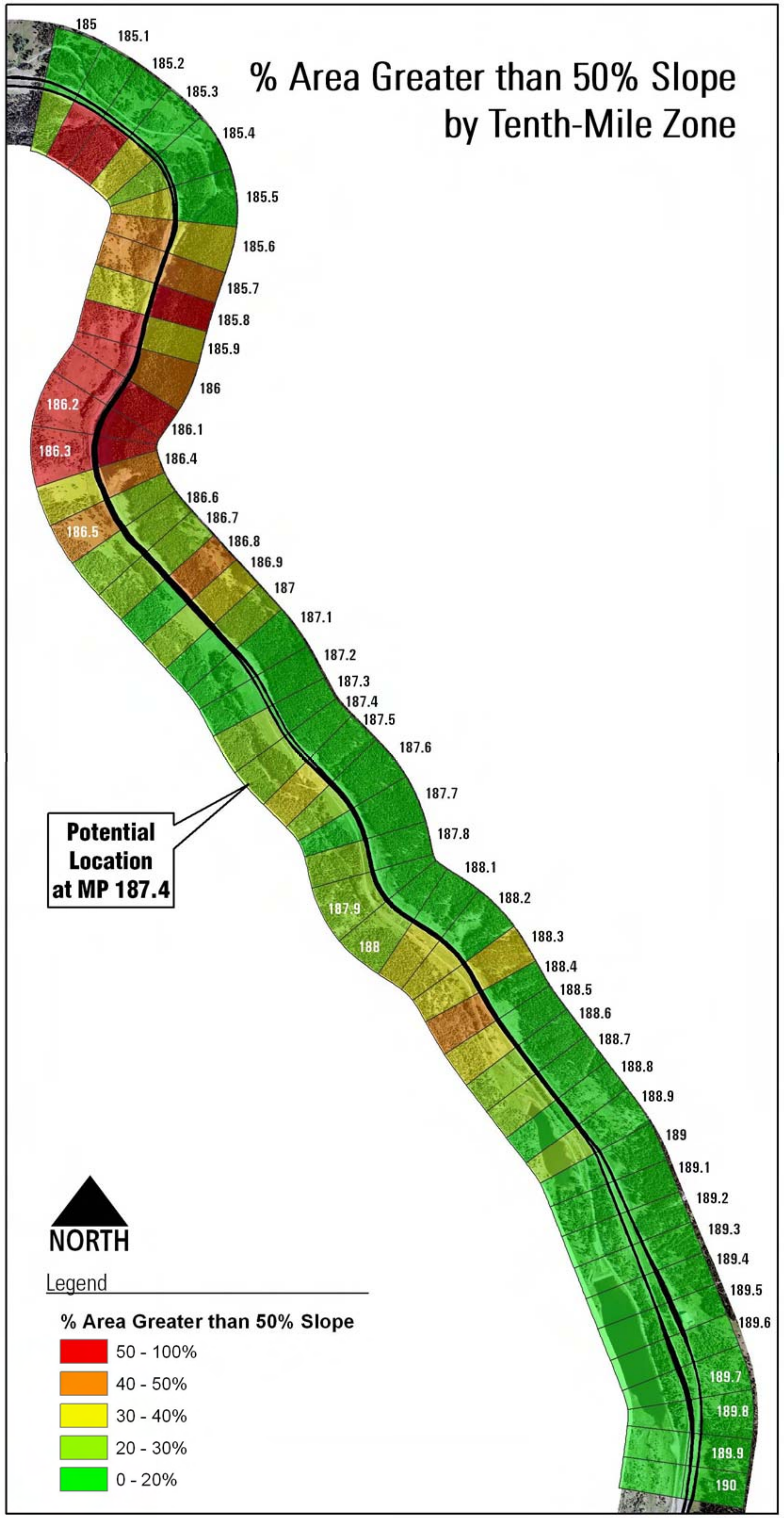


Legend

Shortest Distance to Tree Cover

🟥 500 - 600 Feet
🟧 400 - 500 Feet
🟨 300 - 400 Feet
🟩 200 - 300 Feet
🟩 100 - 200 Feet

% Area Greater than 50% Slope by Tenth-Mile Zone

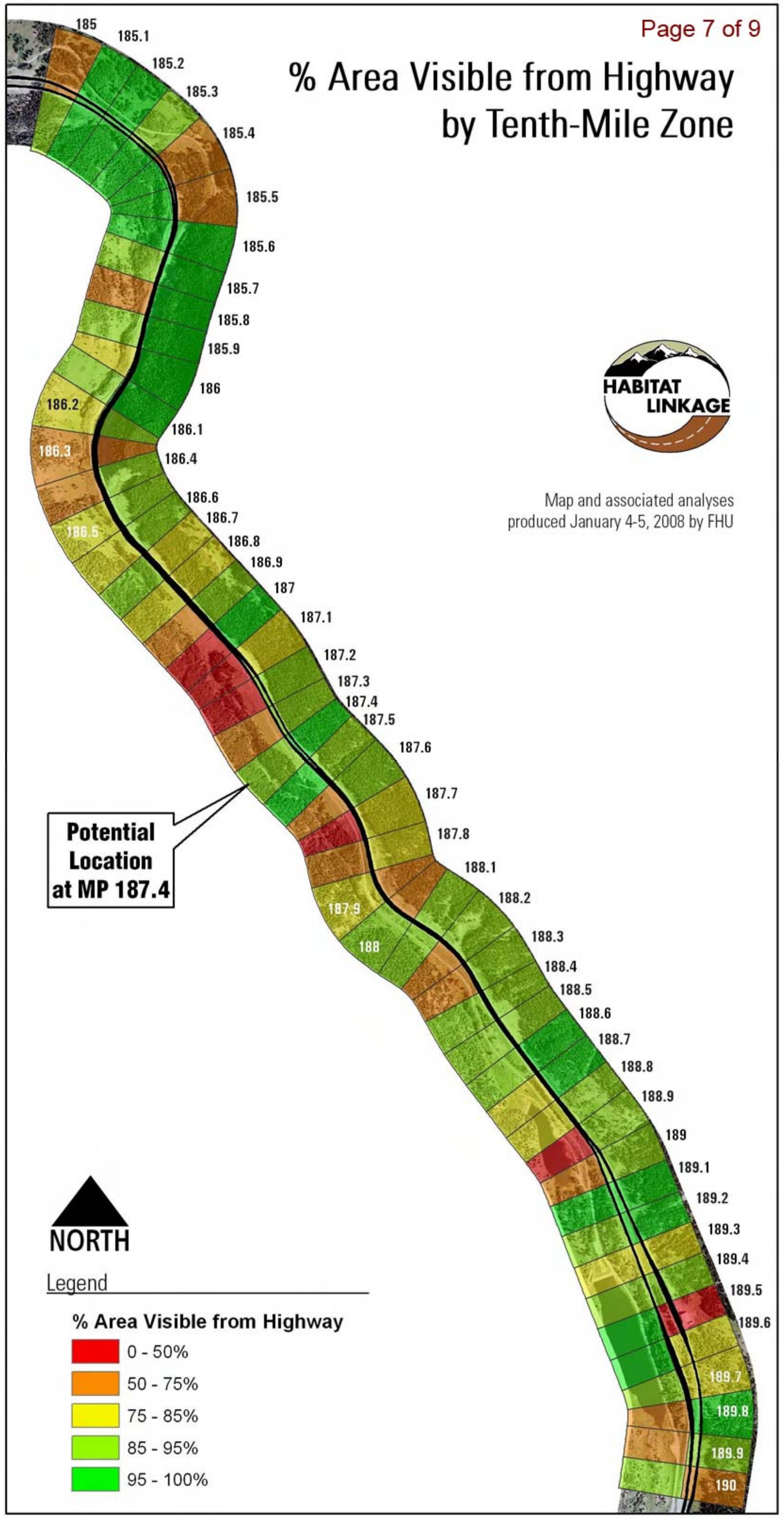


Legend

% Area Greater than 50% Slope

🟥 50 - 100%
🟧 40 - 50%
🟨 30 - 40%
🟩 20 - 30%
🟩 0 - 20%

% Area Visible from Highway by Tenth-Mile Zone

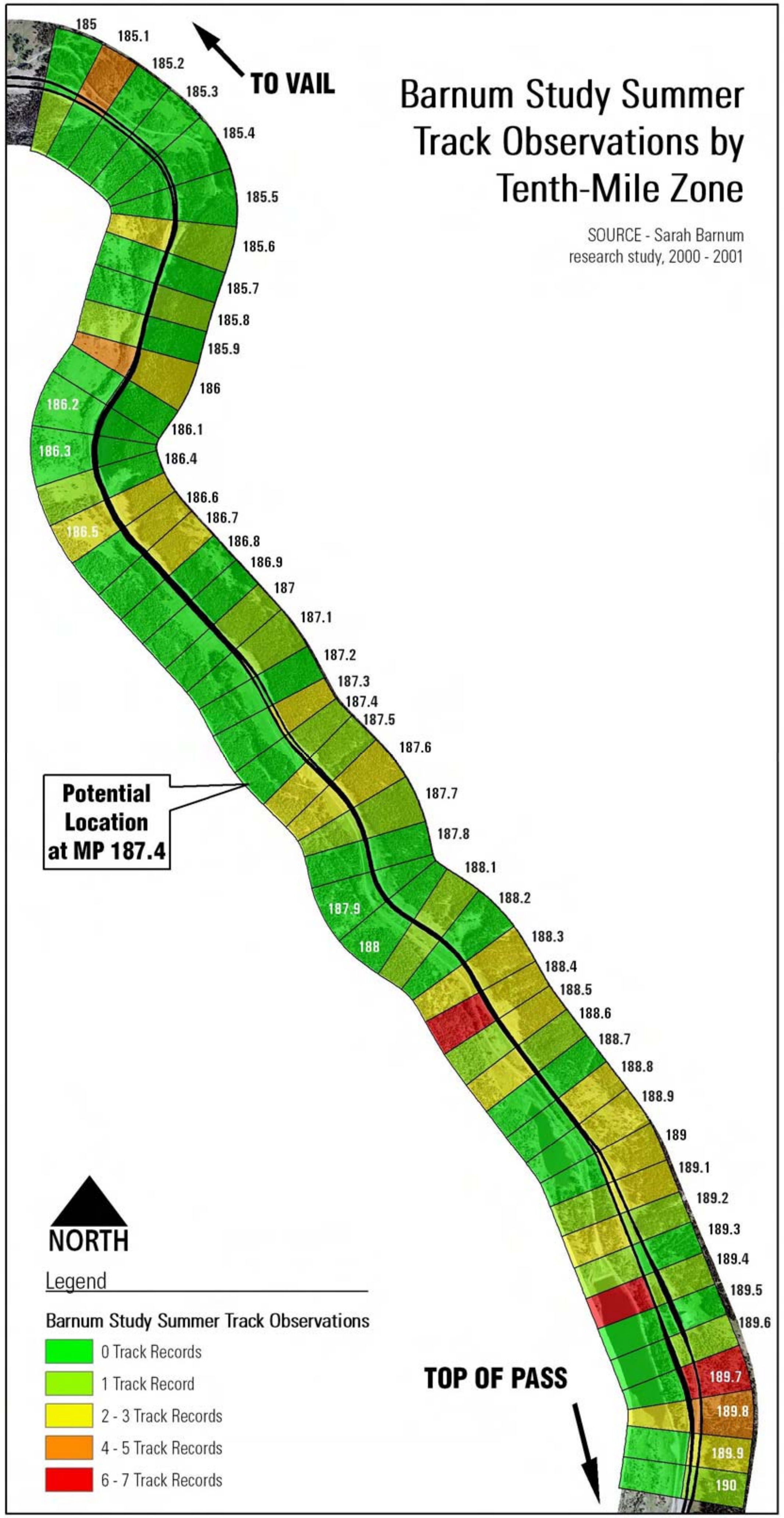


Map and associated analyses produced January 4-5, 2008 by FHU

Legend

% Area Visible from Highway

🟥 0 - 50%
🟧 50 - 75%
🟨 75 - 85%
🟩 85 - 95%
🟩 95 - 100%



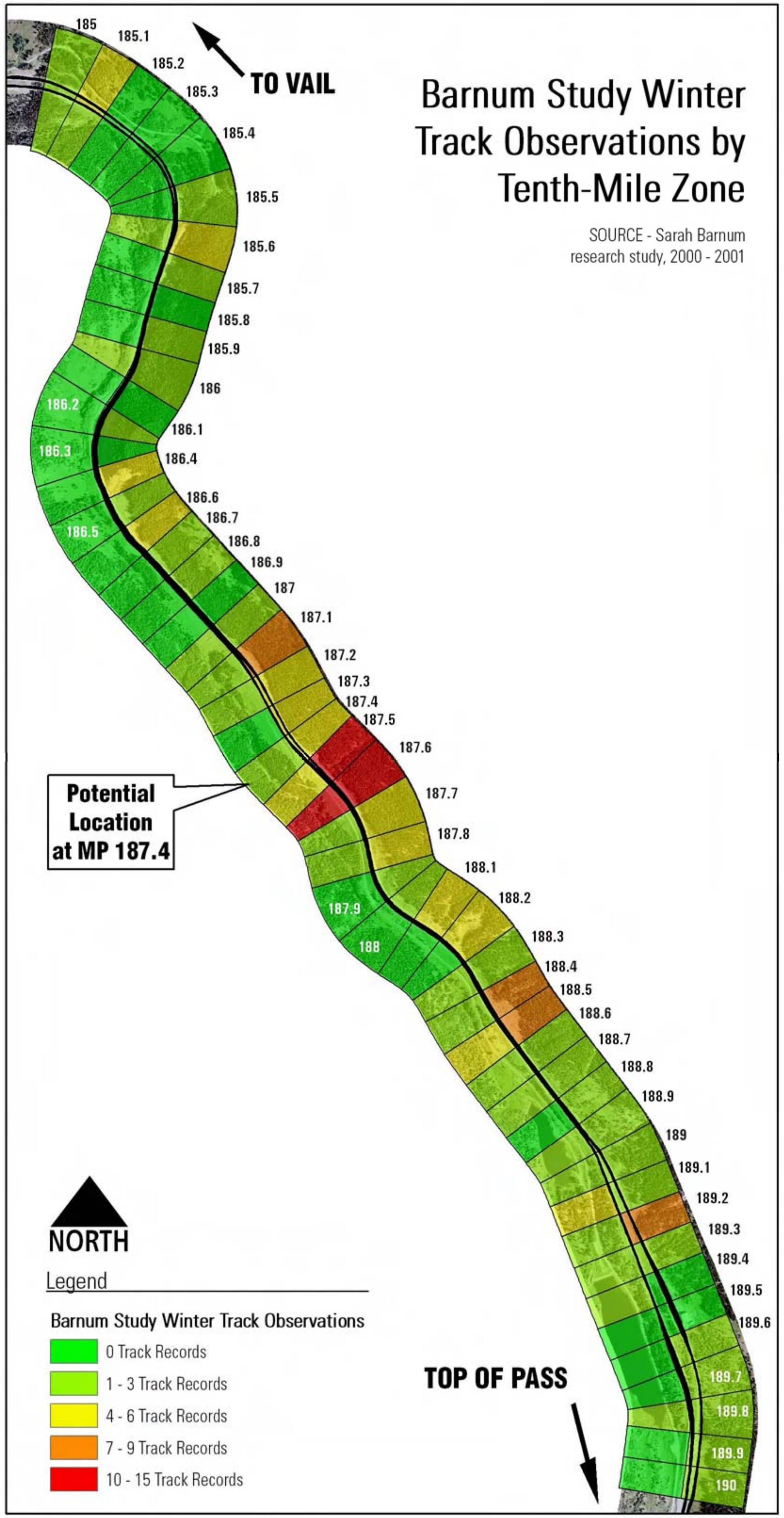
Barnum Study Summer Track Observations by Tenth-Mile Zone

SOURCE - Sarah Barnum research study, 2000 - 2001

Potential Location at MP 187.4

Legend

Barnum Study Summer Track Observations
- 🟩 0 Track Records
- 🟩 1 Track Record
- 🟨 2 - 3 Track Records
- 🟧 4 - 5 Track Records
- 🟥 6 - 7 Track Records



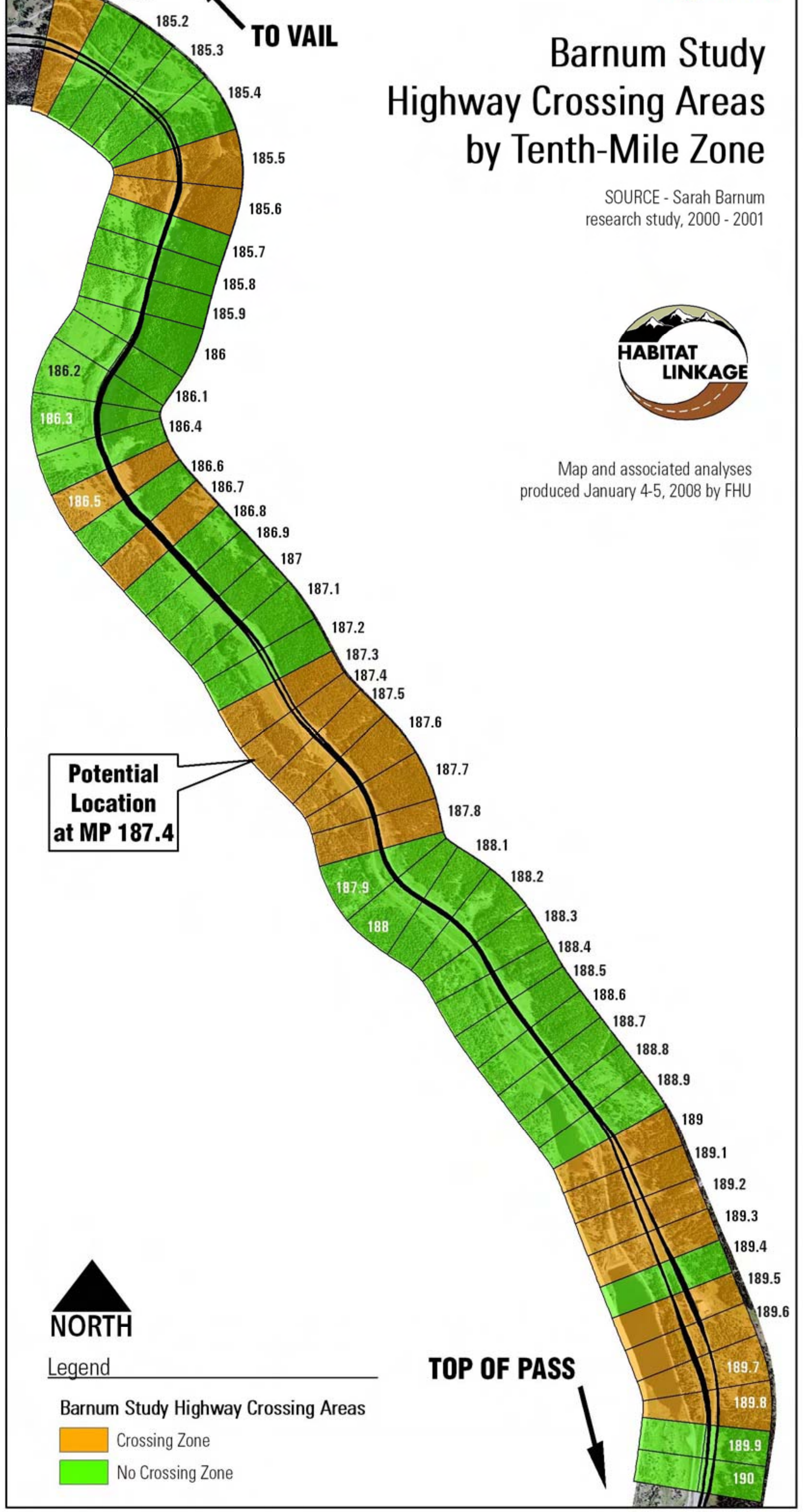
Barnum Study Winter Track Observations by Tenth-Mile Zone

SOURCE - Sarah Barnum research study, 2000 - 2001

Potential Location at MP 187.4

Legend

Barnum Study Winter Track Observations
- 🟩 0 Track Records
- 🟩 1 - 3 Track Records
- 🟨 4 - 6 Track Records
- 🟧 7 - 9 Track Records
- 🟥 10 - 15 Track Records



Barnum Study Highway Crossing Areas by Tenth-Mile Zone

SOURCE - Sarah Barnum research study, 2000 - 2001

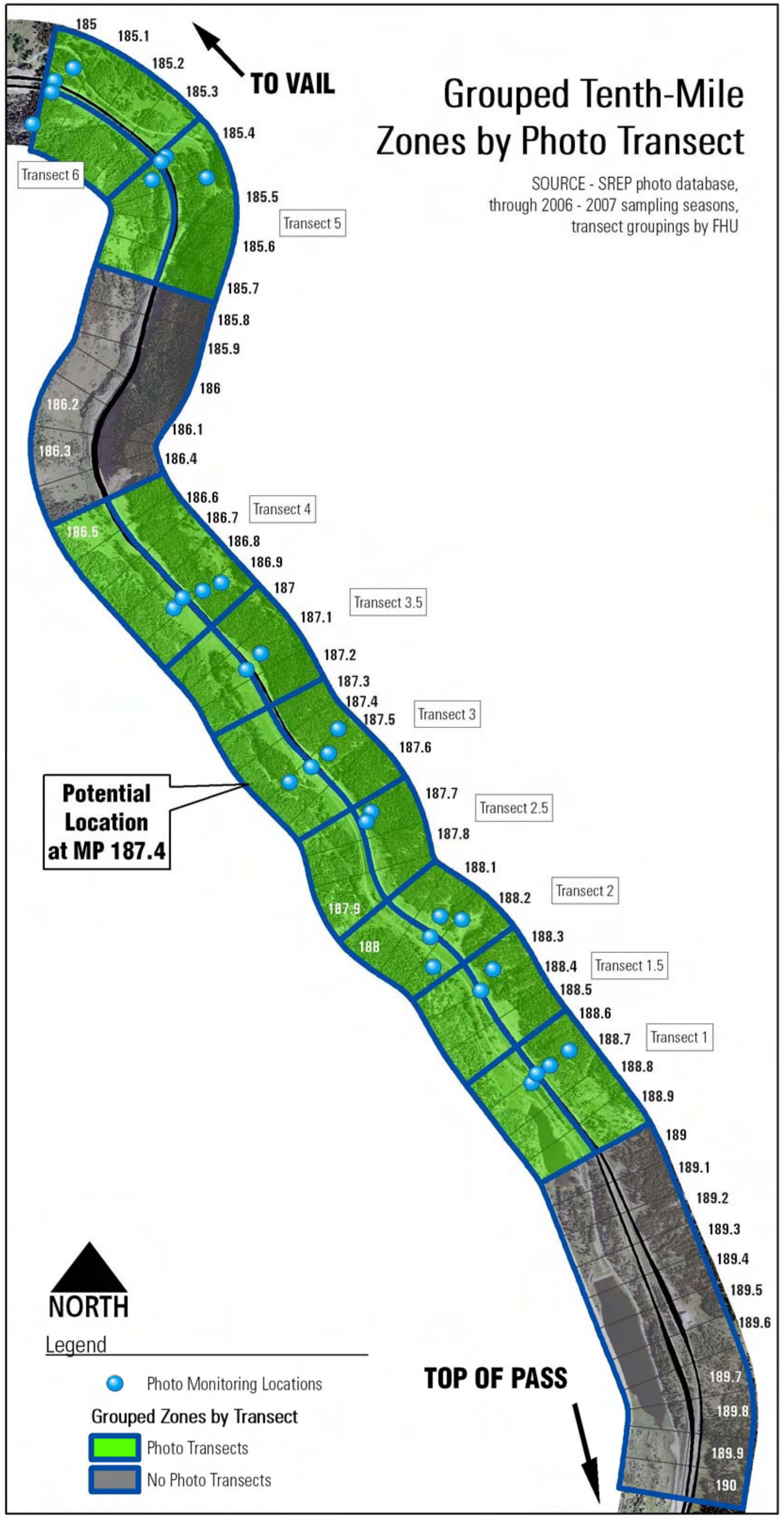
HABITAT LINKAGE

Map and associated analyses produced January 4-5, 2008 by FHU

Potential Location at MP 187.4

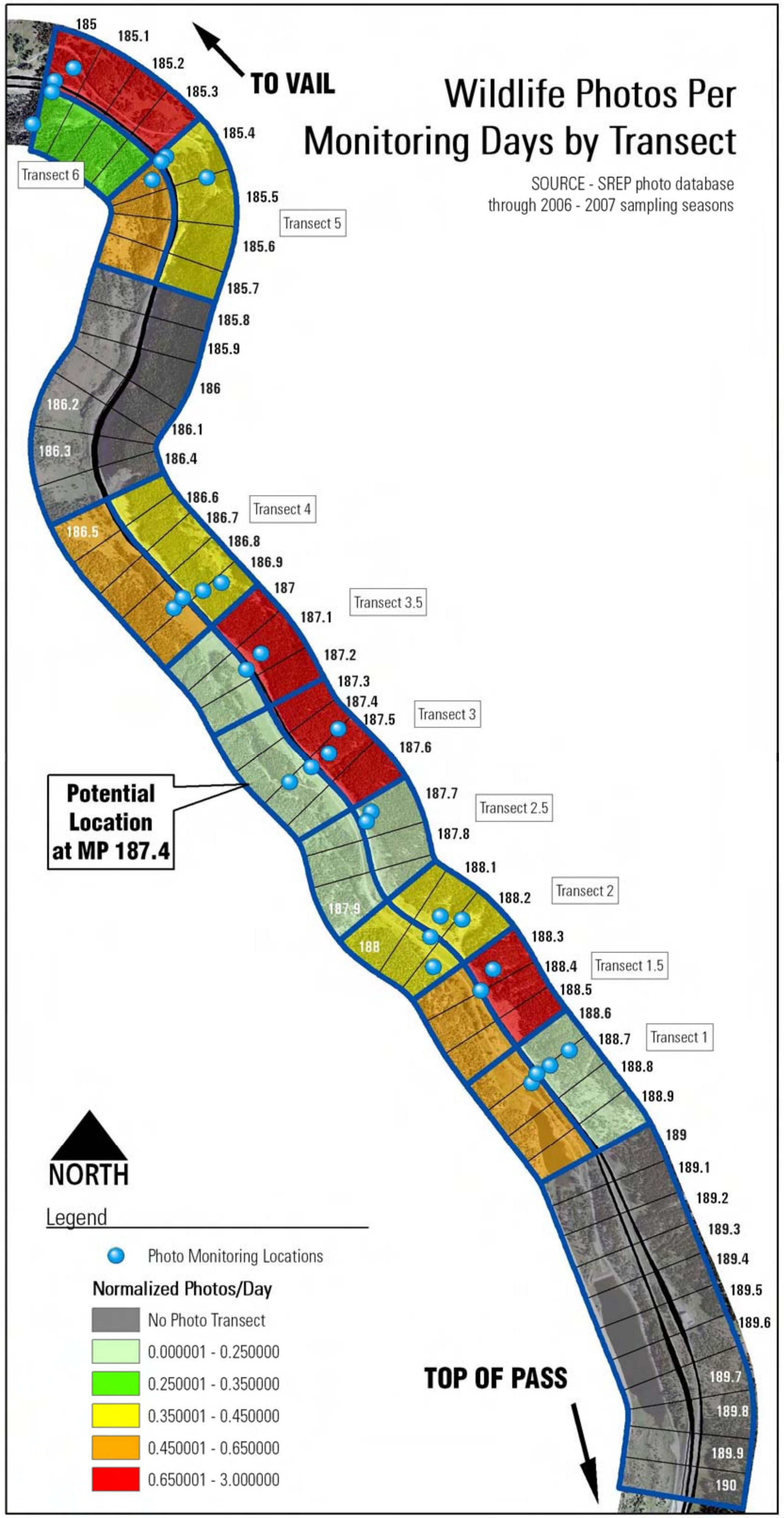
Legend

Barnum Study Highway Crossing Areas
- 🟧 Crossing Zone
- 🟩 No Crossing Zone



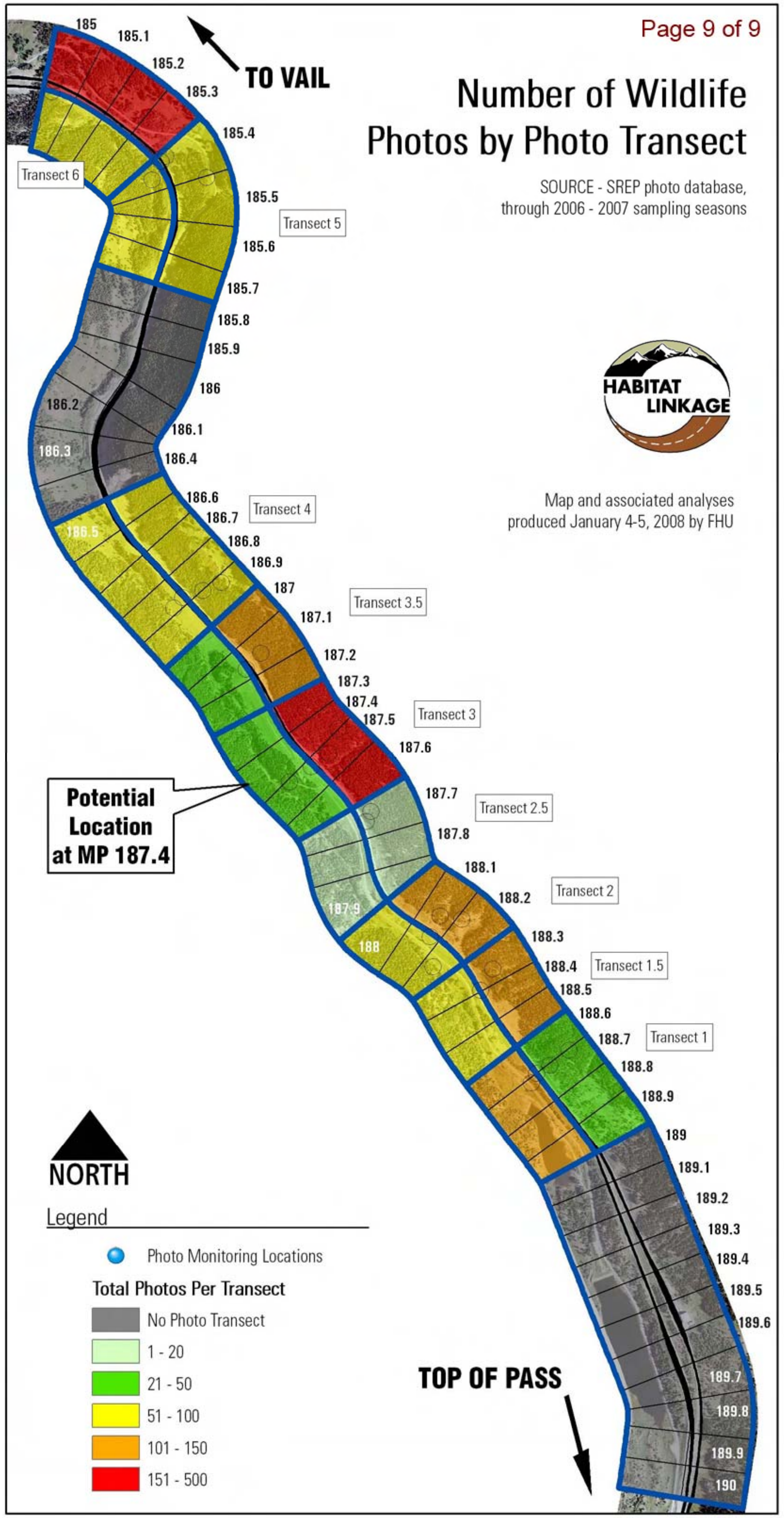
Grouped Tenth-Mile Zones by Photo Transect

SOURCE - SREP photo database, through 2006 - 2007 sampling seasons, transect groupings by FHU



Wildlife Photos Per Monitoring Days by Transect

SOURCE - SREP photo database through 2006 - 2007 sampling seasons

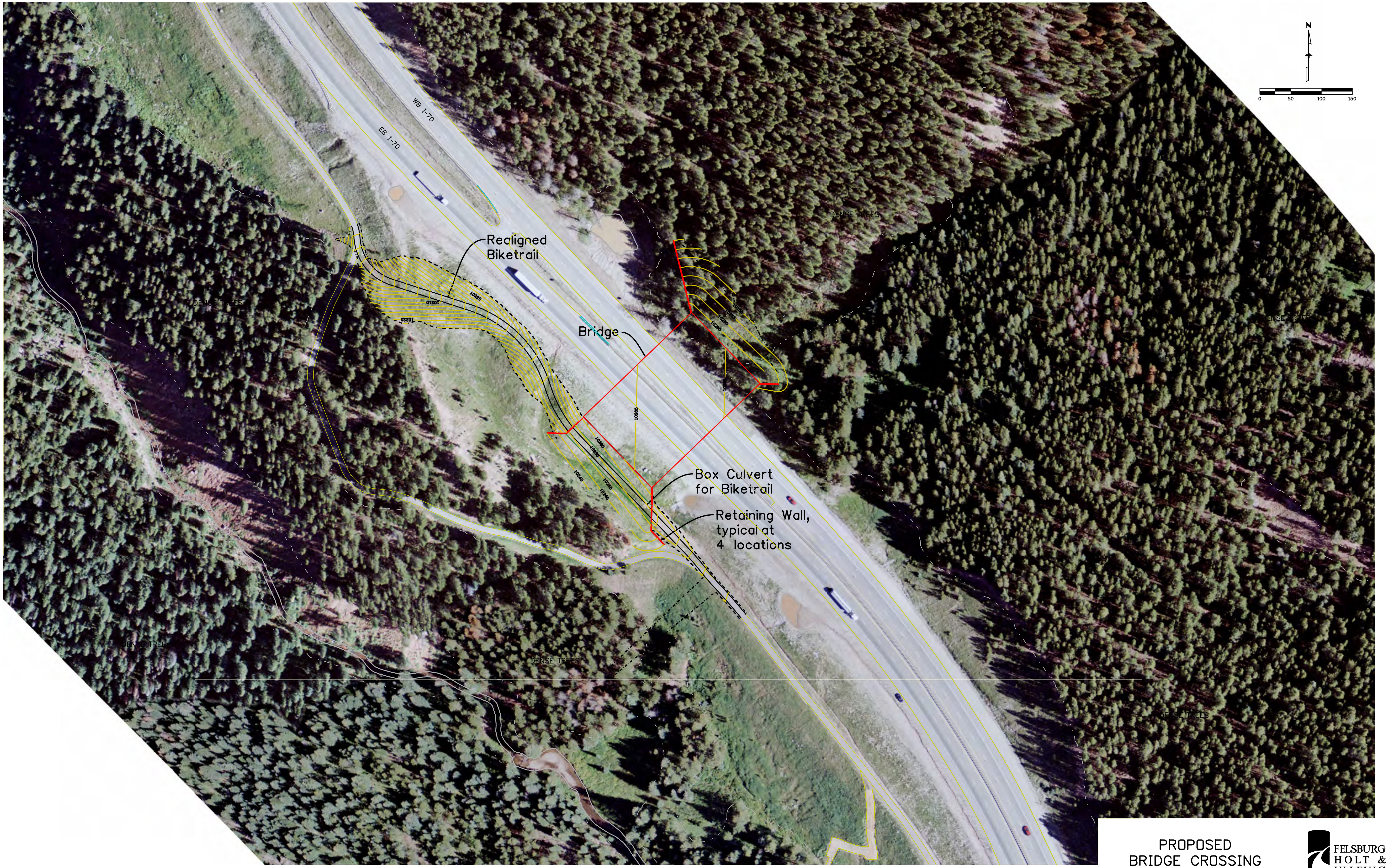


Number of Wildlife Photos by Photo Transect

SOURCE - SREP photo database, through 2006 - 2007 sampling seasons

Map and associated analyses produced January 4-5, 2008 by FHU

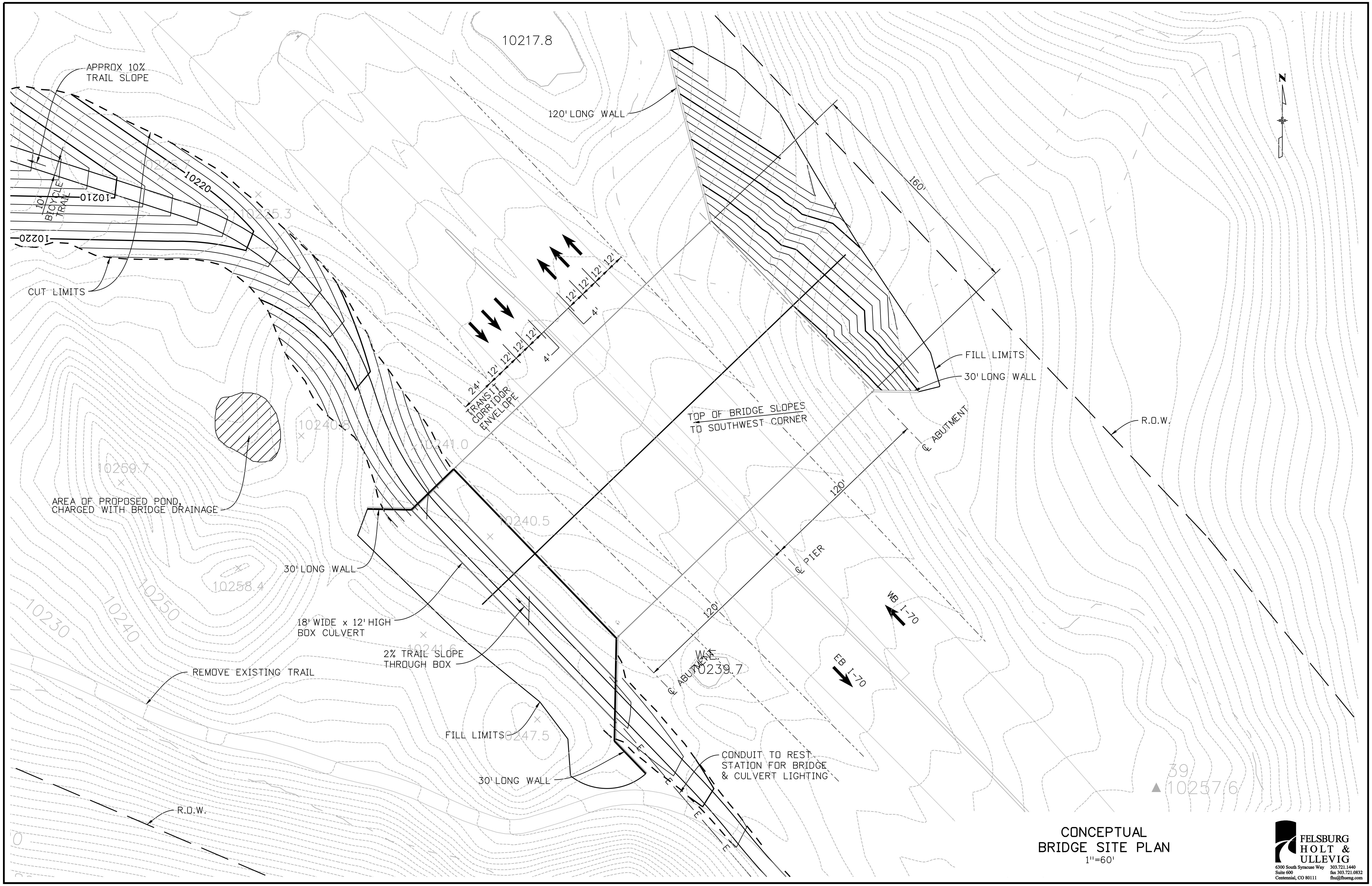
Appendix B
Conceptual Design Drawings



PROPOSED
BRIDGE CROSSING
(I-70 MILE POST 187.4)

FELSBURG
HOLT &
ULLEVIG
6300 South Syracuse Way
Suite 600
Centennial, CO 80111
303.721.1440
fax 303.721.0832
fhu@fhueng.com

Ricdil 3:36:50 PM L:\07227\Bridge\Drawings\15865Bridge_on_Aerial12-28-09.dgn
1/4/2010 CDOT-PDFdriver.pltcfg *

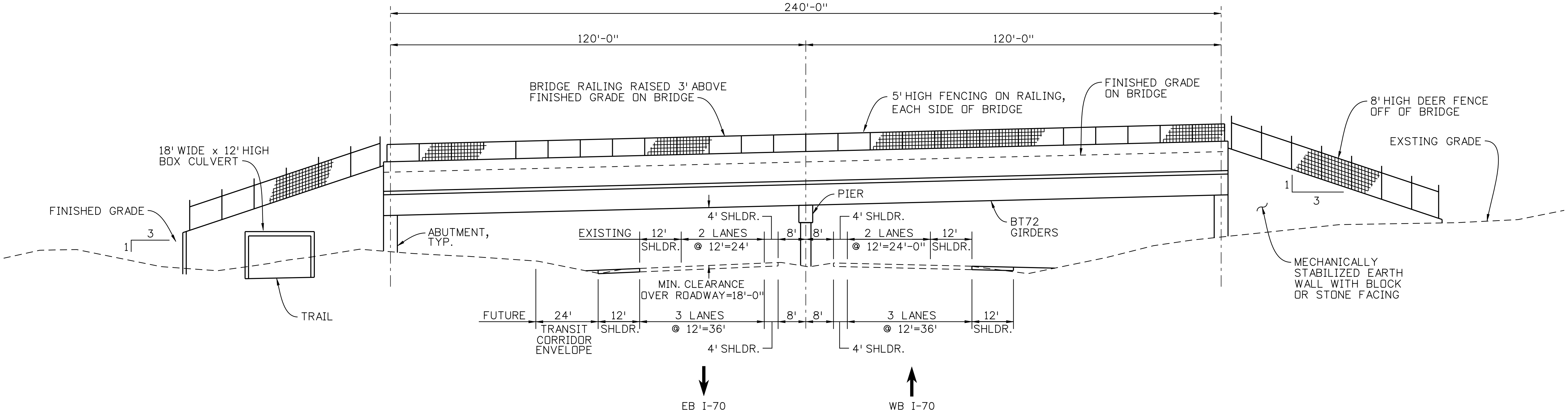


CONCEPTUAL
BRIDGE SITE PLAN
1"=60'

FELSBURG
HOLT &
ULLEVIG

6300 South Syracuse Way
Suite 600
Centennial, CO 80111
303.721.1440
fax 303.721.0832
fhu@fhueng.com

Ricdil 3:35:31 PM L:\07227\Bridge\Drawings\15865BridgeSitePlan12-28-09.dgn
1/4/2010 CDOT-PDFdriver.pltcfg *



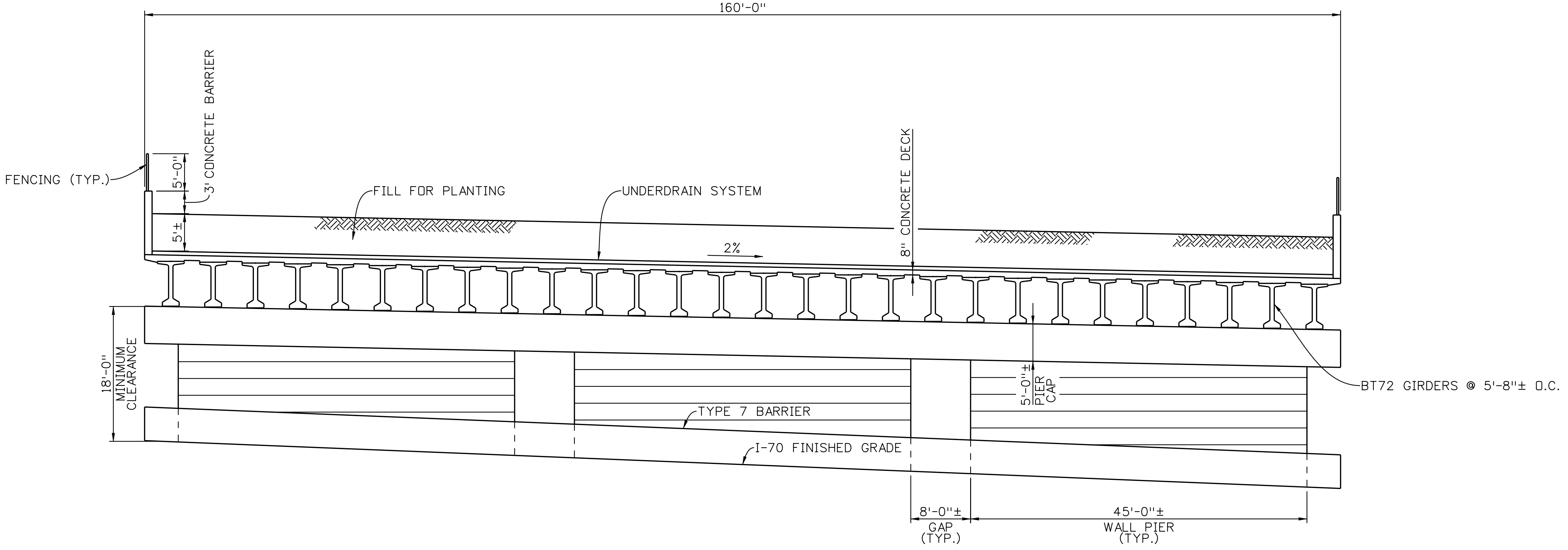
CONCEPTUAL BRIDGE ELEVATION

(FACING WEST)

CONCEPTUAL BRIDGE ELEVATION
1"=60'

FELSBURG
HOLT &
ULLEVIG
6300 South Syracuse Way
Suite 600
Centennial, CO 80111
303.721.1440
fax 303.721.0832
fhu@fhueng.com

Ricdil 3:33:29 PM L:\07227\Bridge\Drawings\15865BridgeElevation12-28-09.dgn
1/4/2010 CDOT-PDFdriver.pltcfg *

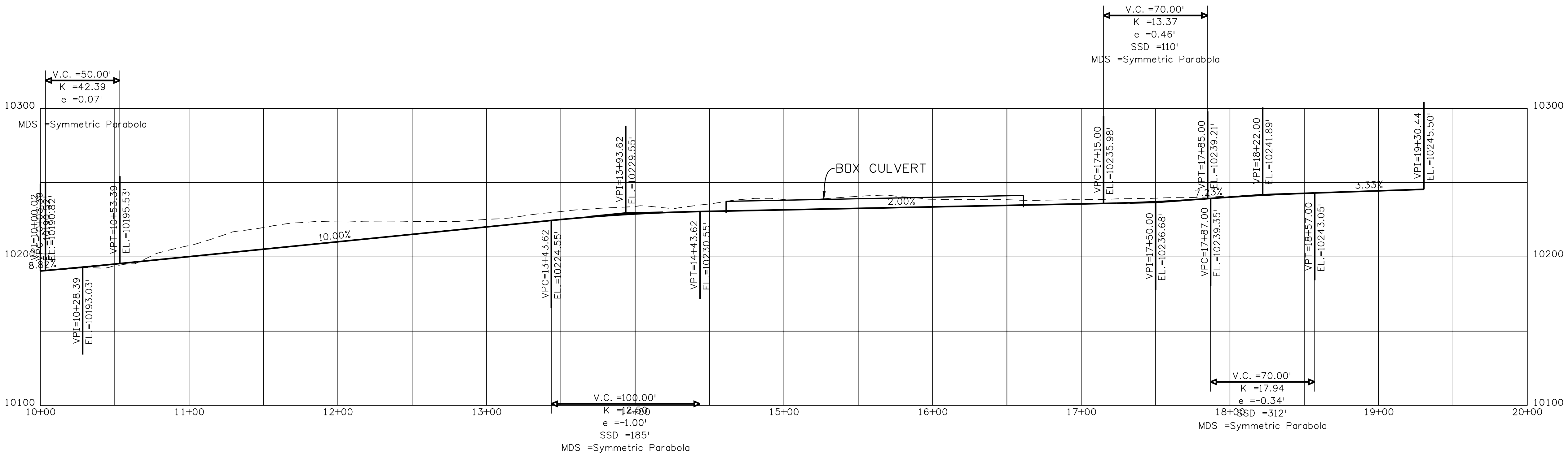


TYPICAL CONCEPTUAL BRIDGE SECTION

Ricdil 3:34:00 PM L:\07227\Bridge\Drawings\15865BridgeSection12-28-09.dgn
1/4/2010 CDOT-PDFdriver.pltcfg *

TYPICAL CONCEPTUAL
BRIDGE SECTION

FELSBURG
HOLT &
ULLEVIG
6300 South Syracuse Way
Suite 600
Centennial, CO 80111
303.721.1440
fax 303.721.0832
fhu@fhueng.com



BIKE TRAIL PROFILE

BIKE TRAIL PROFILE
1"=100' HORIZ.
1"=100' VERT.

FELSBURG
HOLT &
ULLEVIG
6300 South Syracuse Way 303.721.1440
Suite 600 fax 303.721.0832
Centennial, CO 80111 fhu@fhueng.com

Ricdil 3:27:01 PM L:\07227\Bridge\Drawings\15865BikeTrailProfile12-28-09.dgn
1/4/2010 CDOT-PDFdriver.pltcfg *

Appendix C
Geotechnical Report

Draft
Geotechnical Engineering Report
Vail Pass Wildlife Crossing
Eagle County, Colorado

YA Project No. 29-098

July 08, 2009

Prepared for:

Felsburg, Holt & Ullevig
6300 South Syracuse Way, Suite 600
Centenial, Colorado 80111
Attn: Mr. Alex Pulley

Colorado Department of Transportation
Region 3, Eagle Residency
714 Grand Avenue
Eagle, Colorado 81631
Attn: Mr. Peter Kozinski, P.E.

Prepared by:

Yeh and Associates, Inc.
5700 E. Evans Avenue
Denver, Colorado 80222
Phone: 303-781-9590
Fax: 303-781-9583

TABLE OF CONTENTS

LIST OF APPENDICES

PURPOSE AND SCOPE OF STUDY

This report presents the results of our draft geotechnical study for the proposed wildlife crossing bridge to be located approximately 2 miles west of the summit of Vail Pass on Interstate 70 (I-70) in Eagle County, Colorado. The purpose of our study was to evaluate the subsurface geotechnical characteristics of the subsurface materials and conditions, and to provide draft geotechnical recommendations and parameters for the design and construction of the proposed bridge foundation and associated support structures. The study was conducted in general accordance with our proposal.

Yeh and Associates conducted exploratory drilling in order to obtain information on surface and subsurface conditions at the proposed bridge abutment and pier locations. Borings were located in the approximate areas of the proposed abutment and pier locations to the north and south of I-70 and in the westbound left lane of traffic. Subsurface material samples were obtained during the field exploration and examined by the project personnel. A cursory reconnaissance of the overall area was also conducted.

This report summarizes the data gathered; the results of our analysis; and our conclusions and final recommendations based on the proposed construction, site reconnaissance, and geotechnical subsurface investigation. Draft recommendations for foundation design are included in this report.

PROPOSED CONSTRUCTION

The proposed vegetated wildlife crossing is located approximately 2 miles west of the summit of Vail Pass and the CDOT facility. It is our understanding that the proposed bridge will be approximately 160 feet wide, spanning I-70 in order to provide a crossing for wildlife such as elk and mule deer (Figure 1). The proposed bridge will be a double-span structure, approximately 240 feet long.

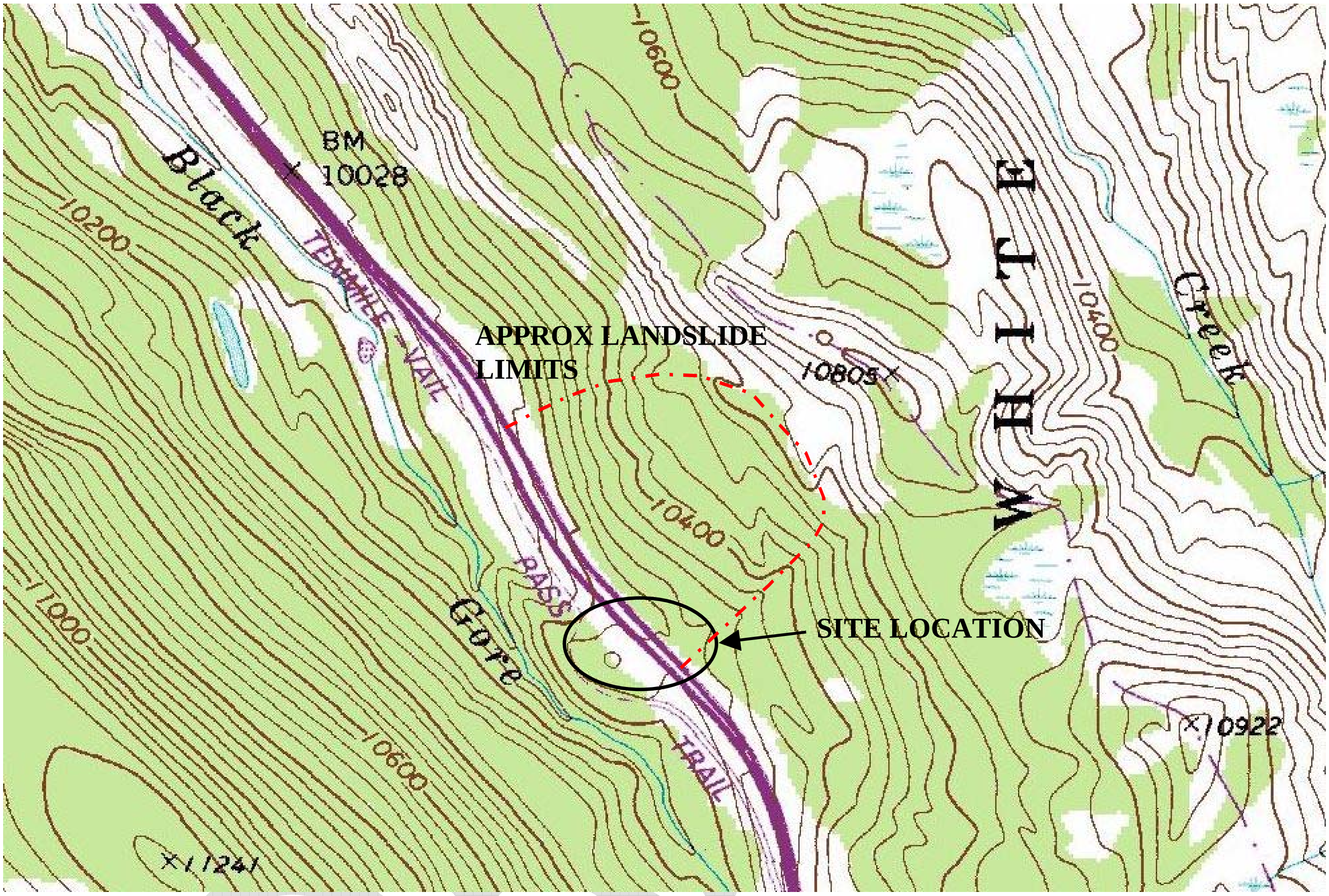


Figure 1 – Site Location Map

SITE CONDITIONS

The site is located 2 miles west of the summit of Vail Pass on I-70 at milepost 187. The site is at the base of a moderately sloping drainage formed by Black Gore Creek and is at an approximate elevation of 10,250 feet. Steeply sloping sections and hummocky displaced bedrock are found within the drainage. Currently, there are four lanes of traffic where the wildlife crossing is proposed. Above the crossing site is a steep, narrow gulch that appears to have periodic debris flow events that have the potential to impact the roadway periodically (Figure 2). Water flow on the slope is also in the form of seeps and springs and varies seasonally.

Figure 2 – Debris Flow Channel Looking South towards I-70.

GEOLOGIC CONDITIONS

The geology of the site was investigated by reviewing published geologic maps, analyzing aerial photographs, performing a cursory field study, and testing of samples obtained from the exploratory drilling. The interpretation of the site geology is based upon this information and our experience with similar projects in the area.

The site geology exhibits characteristics of a deep-seated landslide system that extends many hundreds of feet eastbound and westbound of the site. Based on a cursory field review of the site it appears the landslide system is related to large scale faulting and Pleistocene glacial activity. As shown in Figure 3 there is a fault crossing near the project location. The site geology consists of a varying thickness of surficial deposits overlying bedrock. The following sections discuss the various geologic units.

BEDROCK

Bedrock in the site vicinity has been mapped by the United States Geological Survey (USGS) as being Pennsylvanian Maroon and Minturn Formation; both formations can consist of fine to coarse grained arkosic sandstone, conglomerate, and shale (Figures 3 and 4). Within the project area, the outcrops are moderately to highly weathered. Bedrock at and above the site was oriented in various orientations at the surface outcrops. Outcrops appeared to have stepped graben features as the bedrock angles were inconsistent.

SURFICIAL DEPOSITS

The surficial material to the north east of the site is mapped as Holocene and Pleistocene landslide deposits by the USGS that are not currently active. Based on exploratory drilling the surface material is at least 70 feet deep, however bedrock undisplaced bedrock may be 200 to 300 feet deep in this location (assuming the elevation of the stream is on bedrock). Surficial materials include cobbles and boulders of the Minturn and Maroon formations that range in size from 3 feet to 10 feet in diameter. Frozen soil conditions were encountered at 60 feet and 65 feet in boring YA-P1b and recorded temperatures can be found in Appendix B. Temperature of the soil was determined with an analog probe-style thermometer.

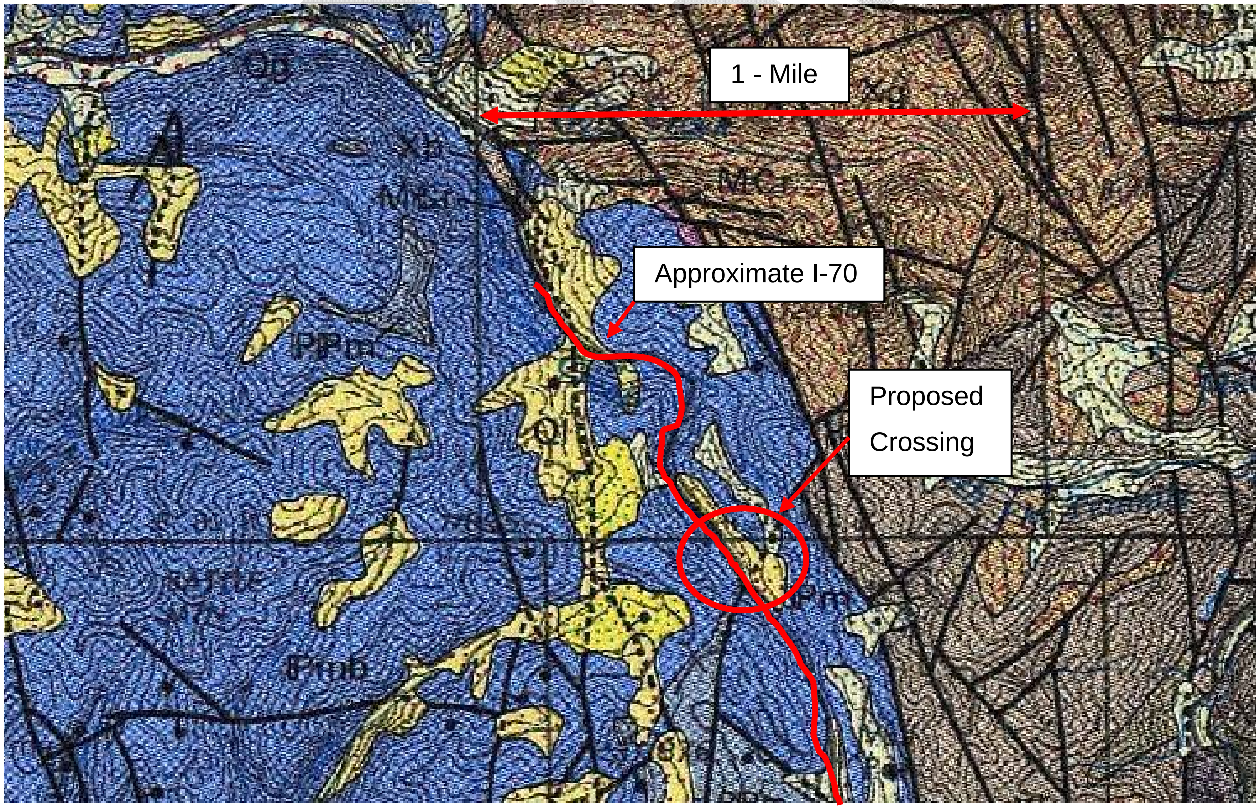
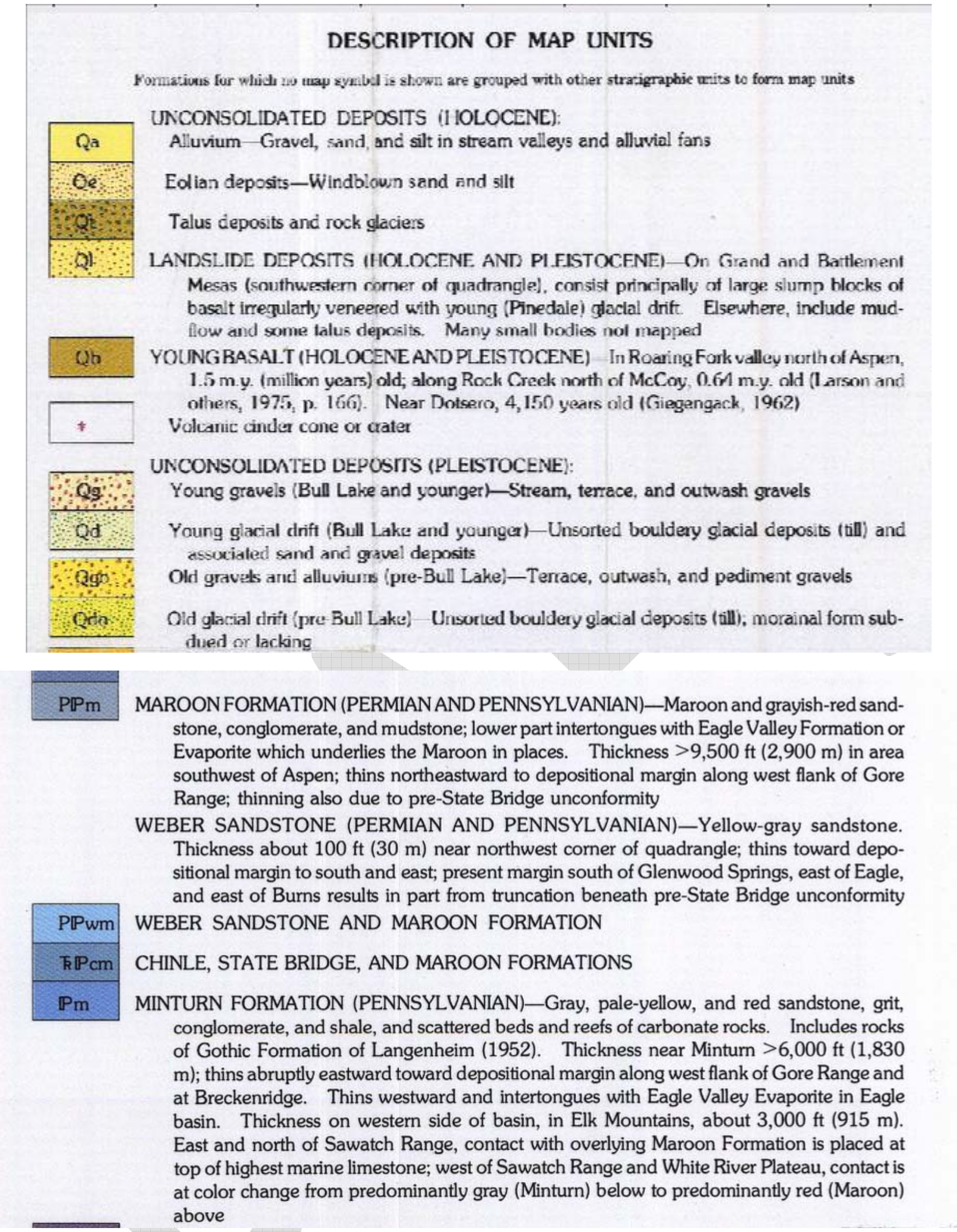


Figure 3 – USGS Map with Approximate Project Location



DESCRIPTION OF MAP UNITS

Formations for which no map symbol is shown are grouped with other stratigraphic units to form map units

UNCONSOLIDATED DEPOSITS (HOLOCENE):

Qa	Alluvium—Gravel, sand, and silt in stream valleys and alluvial fans
Qe	Eolian deposits—Windblown sand and silt
Qt	Talus deposits and rock glaciers
Ql	LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)—On Grand and Battlement Mesas (southwestern corner of quadrangle), consist principally of large slump blocks of basalt irregularly veneered with young (Pinedale) glacial drift. Elsewhere, include mudflow and some talus deposits. Many small bodies not mapped
Qb	YOUNG BASALT (HOLOCENE AND PLEISTOCENE)—In Roaring Fork valley north of Aspen, 1.5 m.y. (million years) old; along Rock Creek north of McCoy, 0.64 m.y. old (Larson and others, 1975, p. 166). Near Dotsero, 4,150 years old (Giegengack, 1962)
*	Volcanic cinder cone or crater

UNCONSOLIDATED DEPOSITS (PLEISTOCENE):

Qg	Young gravels (Bull Lake and younger)—Stream, terrace, and outwash gravels
Qd	Young glacial drift (Bull Lake and younger)—Unsorted bouldery glacial deposits (till) and associated sand and gravel deposits
Qgo	Old gravels and alluviums (pre-Bull Lake)—Terrace, outwash, and pediment gravels
Qdo	Old glacial drift (pre Bull Lake)—Unsorted bouldery glacial deposits (till); morainal form subdued or lacking

PIPm	MAROON FORMATION (PERMIAN AND PENNSYLVANIAN)—Maroon and grayish-red sandstone, conglomerate, and mudstone; lower part intertongues with Eagle Valley Formation or Evaporite which underlies the Maroon in places. Thickness >9,500 ft (2,900 m) in area southwest of Aspen; thins northeastward to depositional margin along west flank of Gore Range; thinning also due to pre-State Bridge unconformity
	WEBER SANDSTONE (PERMIAN AND PENNSYLVANIAN)—Yellow-gray sandstone. Thickness about 100 ft (30 m) near northwest corner of quadrangle; thins toward depositional margin to south and east; present margin south of Glenwood Springs, east of Eagle, and east of Burns results in part from truncation beneath pre-State Bridge unconformity
PIPwm	WEBER SANDSTONE AND MAROON FORMATION
ѢIPcm	CHINLE, STATE BRIDGE, AND MAROON FORMATIONS
IPm	MINTURN FORMATION (PENNSYLVANIAN)—Gray, pale-yellow, and red sandstone, grit, conglomerate, and shale, and scattered beds and reefs of carbonate rocks. Includes rocks of Gothic Formation of Langenheim (1952). Thickness near Minturn >6,000 ft (1,830 m); thins abruptly eastward toward depositional margin along west flank of Gore Range and at Breckenridge. Thins westward and intertongues with Eagle Valley Evaporite in Eagle basin. Thickness on western side of basin, in Elk Mountains, about 3,000 ft (915 m). East and north of Sawatch Range, contact with overlying Maroon Formation is placed at top of highest marine limestone; west of Sawatch Range and White River Plateau, contact is at color change from predominantly gray (Minturn) below to predominantly red (Maroon) above

Figure 4: Geologic map and legend of the Leadville Quad, NW Colorado.

SUBSURFACE INVESTIGATION

EXPLORATORY DRILLING

Yeh and Associates, Inc. performed a subsurface drilling program between June 4th and 15th, 2009. Precision Sampling of Colorado Springs, Colorado, was contracted to drill difficult-access borings using a track mounted CME 55 drill rig. Traffic control during drilling was provided by Highway Technologies of Denver, Colorado. A total of four geotechnical boreholes were drilled using 4-inch solid stem auger and 8-inch hollow-stem auger, with a total drilling footage of 246 feet. One of the borings was re-drilled because of a mechanical breakdown. The borings did not encounter bedrock Refusal typically occurred on boulders and/or displaced bedrock that was likely greater than 5 feet in diameter. The borings were located within CDOT right of way. Approximate boring locations can be found in Appendix A. Engineering Geology Sheets, and boring logs are presented in Appendix B. A summary of these borings is included in Table 1.

Table 1: Summary of Borings Drilled

Boring	Depth to Water (ft)	Total Depth (ft)
YA-A1	4	58
YA-A2	1	68
YA-P1a	14, *45 frozen*	70
YA-P1b	11, *60 frozen*	50

Due to bedrock encountered at a depth greater than anticipated, some of the planned borings were not completed. Two borings for retaining wall design were not completed next to boring YA-A1. Drilling also found frozen soil conditions from approximately 45 feet to 65 feet in borings P1a and P1b. Frozen conditions were first noticed in boring P1a but were not confirmed with temperature readings. The frozen condition was discovered because the samples were cold immediately after being removed from the sampling barrel. Subfreezing temperatures to 18 degrees Fahrenheit were later confirmed with a thermometer in boring P1b.

LABORATORY TESTING

Samples retrieved during the field exploration were returned to the laboratory for observation by the project geotechnical engineer and were classified in accordance with the Unified Soil Classification System. An applicable program of laboratory testing was developed to determine engineering properties of the subsurface materials. Following the completion of the laboratory testing, the field descriptions were confirmed or modified as necessary and Logs of Borings were prepared. These logs are presented in Appendix A. Laboratory test results are presented in Appendix B. Laboratory tests were performed in general accordance with the applicable local or other accepted standards. Subsurface materials classified as sandy silts and clayey sands however it should be noted the samples only reflect what was collected in the sample, large cobbles, boulders, and displaced bedrock fragments comprise an estimated 20 to 40 percent of the subsurface materials.

WATER SOLUBLE SULFATES

The concentration of water soluble sulfates measured in soil samples obtained from the exploratory borings ranges from 0.002 percent to 0.008. This concentration of water soluble sulfates represents a Class 0 degree of sulfate attack on concrete exposed to soils in this project area as specified in the Revision of Sections 601 and 701 of the CDOT Standard Special Provisions, presented in Table 601-4 of the CDOT Standard Specification for Structural Concrete, revised on July 3, 2008. All concrete exposed to on-site soils should conform to the requirements of the CDOT specifications.

CORROSION

Test results on acidity of the obtained soil samples indicated pH levels in the range of 8.0 to 9.0, which is slightly basic.

SEISMICITY

Based on the AASHTO LRFD Bridge Design Specifications (2008 Interims) the site classifies as a Class D for seismic loading (Table 3.10.3.1-1) for soils at a depth of 15 feet or greater. For soils from 0 to 15 feet the site classifies as Class E. According to the USGS Seismic design Parameters software (Version 2.10) a factored peak ground acceleration (PGA) of 0.077 g (g = gravity) may be used for this site with a 7% probability of exceedance in 75 years (Approximate 1000-year Return Period Outlined by AASHTO).

GROUNDWATER CONDITIONS

Groundwater was observed in the test borings at the time of field exploration at depths of about 1 to 14 feet below existing site grade in the test borings at the time of field exploration. Seeps and springs were also observed above the site during field reconnaissance. These observations represent groundwater conditions at the time of the field exploration, and may not be indicative of other times or at other locations. Groundwater conditions can change with varying seasonal, irrigation and weather conditions and other factors.

GEOLOGIC CONSTRAINTS

LANDSLIDES

Based on a cursory field investigation and review of the previous mapping by others, the project site and adjacent areas are located in an ancient, deep-seated landslide that is likely not as active as it has been in the geologic past. Large sections of rotated and displaced bedrock were observed above the project site most likely from the effects of large scale landslides and/or glacial activity in the Pleistocene (Figure 5). Reconnaissance in the drainage below the site indicates the landslide could be 300 feet thick or more.

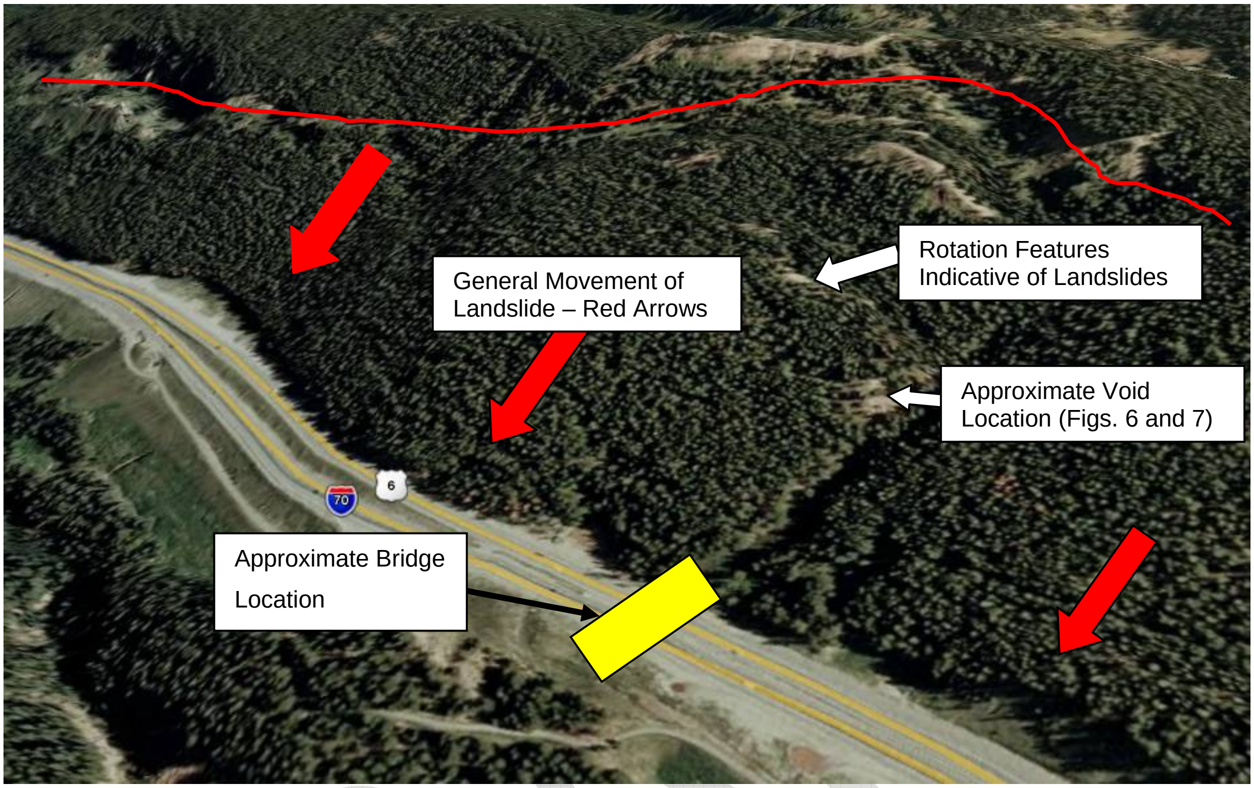


Figure 5. Below Red Line Depicts General Area of Ancient Landslide Deposits

GLACIAL REMNANT

Based on the temperature of the samples and geologic history of the Vail Pass area, there are possible glacial related features buried in or forming part of the landslide. No ice was visible in the frozen samples, but frozen conditions were verified with a thermometer as shallow as 45 feet. There have been similar materials found in rock glaciers on north facing slopes at approximately 11,500 feet and it is likely the source of the frozen materials.

LARGE SCALE FAULTING

Large scale faulting may have triggered or be related to the landslide structures at the site. The high degree of variation in the bedrock orientation was observed at the site. Rotational steppe features were also observed that could be related to fault structures.

DEBRIS FLOW POTENTIAL

There appears to be the potential for debris flows to impact the north abutment structure if it is located within the drainage area. While it is likely not a hazard that will preclude this location for the proposed structure, it is a geologic event that should be considered.

POTENTIAL VOIDS AT PROJECT SITE

Based on our cursory field reconnaissance, it appears that the displaced bedrock blocks within the landslide can form block supported voids that create openings in excess of 2 feet in diameter with depths of 10 to 20 feet. Figures 6 and 7 depict a void anomaly that is located approximately 300 feet north of the proposed bridge structure. No voids were encountered in the borings at the proposed abutments and pier locations, however we have noted voids to document that they exist in the area.

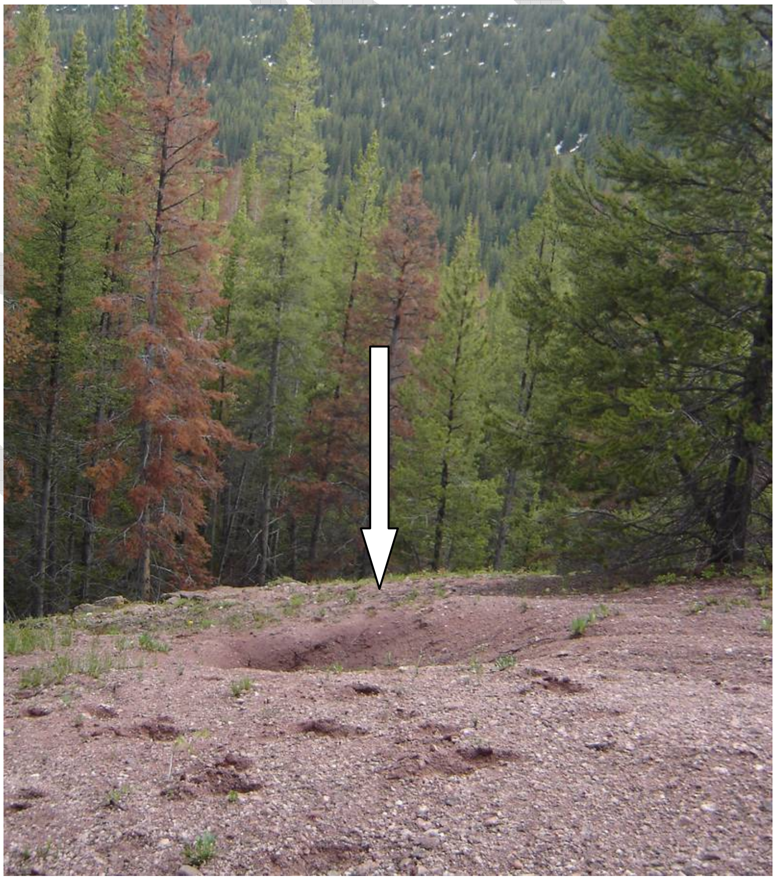


Figure 6. Arrow Depicts Surface Expression of Void North of Proposed Site

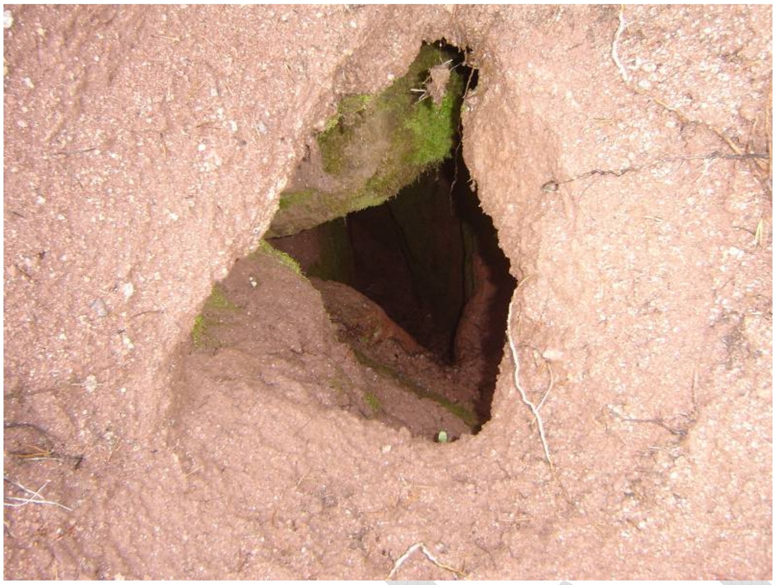


Figure 6. Looking Down Void North of Proposed Site

BRIDGE FOUNDATION CONSIDERATIONS

ADDITIONAL INVESTIGATION

Overall the proposed structure location is within an ancient landslide complex with frozen materials located at depth below the pier. Prior to final design and to verify the preliminary assumptions we would recommend the following:

1. Additional Coring Investigation. We would recommend core type boring method at the proposed abutments and pier location. Coring methods will provide a better evaluation of the subsurface materials. It is estimated the cored holes would need to be advanced to at least 200 feet to provide a reasonable estimate to bedrock.
2. Inclinometers. At least two inclinometers would need to be installed to a depth of at least 200 feet (or shallower if bedrock is encountered) to verify the activity of the landslide feature. The USGS classifies the landslide as “inactive” but that indicates the slide has the potential to move up to an inch a year if reactivated.
3. Field Reconnaissance of the Landslide Area. Yeh and Associates, Inc provided a cursory reconnaissance of the field area, but a more detailed

mapping of the large scale landslide feature would be needed to verify the extents.

PRELIMINARY DESIGN OF BRIDGE

At this time we assume the bridge is located within a landslide that has the potential to move over time. Regardless of the activity of the landslide, it would be prudent to design the bridge structure and foundations to tolerate some degree of movement over the design life of the structure. Based on similar landslides of this nature, we estimate at least ¼ to 1 inch of potential movement over a five to ten year period (inclinometers will need to be installed and monitored to verify this assumption).

Based on the nature of the subsurface materials (frozen materials, etc) and potential movement of the landslide it may be possible to locate the foundations on shallow footings if the bridge can tolerate movement. Driven piles may also be an option if the design in the frozen sections would not affect or thaw the subsurface materials.

Design parameters are based on the AASHTO LRFD Bridge Design Specifications, Fourth Edition, 2008 Interims.

RESISTANCE FACTORS - SHALLOW FOUNDATIONS FOR BRIDGE

1. Using Load Resistance Factor Design criteria (LRFD) for a Strength Limit State, a nominal ultimate bearing capacity of 8.0 ksf (for depths less than 15 feet) to 12.0 ksf (for depths greater than or equal to 15 feet) may be used depending on the location. This assumes an average load factor of 1.45 and a bearing resistance factor of 0.45. At the discretion of the design engineer, the resistance factor may be increased if QC techniques are used during construction (i.e. Plate Load Test). Resistance to sliding at the bottom of the footing can be calculated based on a resistance factor of 0.8 for Cast-In-Place Concrete on Sand (Table 10.5.5.2.2-1). Passive pressure against the side of the footing can also be considered to be 0.50 for the sliding resistance if it is properly compacted.

RESISTANCE FACTORS - RETAINING WALLS

1. Using Load Resistance Factor Design criteria (LRFD), a nominal ultimate bearing capacity of 8.0 (for depths less than 15 feet) to 12.0 ksf (for depths greater than or equal to 15 feet) may be used. This assumes an average load factor of 1.45 and a bearing resistance factor of 0.55 for Gravity Walls and a bearing resistance factor of 0.65 for MSE Walls. The Sliding Resistance can be calculated based on a resistance factor of 1.0 for Gravity and MSE Walls (Table 11.5.6-1)
2. A coefficient of friction of 0.45 may be used for the calculation of sliding resistance when performing an external stability check.
3. An equivalent fluid unit weight of 35 pcf for backfill consisting of compacted Structural Backfill may be used for design.
4. The walls should be designed with an appropriate surcharge pressure for traffic.
5. Sloping toes below the walls and global stability should be evaluated on a case-by case basis.

DRIVEN STEEL H PILES

If it is determined that landslide movements are negligible (by monitoring of inclinometers recommended to be installed under further investigation) and the frozen conditions are accounted for in the design, the following preliminary geotechnical recommendations can be used for pre-drilled steel H-piles for the bridge abutments and the pier locations for the project.

The subsurface materials at the site should be suitable for pile driving based on the blow counts from the subsurface investigation, depending on the Contractor's means and methods. However, pre-drilling may be required if large cobbles and/or boulders are encountered (i.e. boulders greater than 3 to 5 feet in diameter). Pre-drilling should be performed in accordance with the Colorado Department of Transportation (CDOT) Standard Specifications and appropriate Staff Bridge Special Provisions. Pre-drilled holes for piles should be advanced to design pile tip elevation. Pre-drilling may be accomplished by either of two methods:

Method 1 – Drill holes with a minimum diameter 2 inches larger than the web depth of the H piles or,

Method 2 – Drill small-diameter holes and use explosives to blast and fracture large rocks or boulders as they are encountered.

If pre-drilling Method 1 is used, lateral capacity may be significantly reduced and should be evaluated by load testing during construction.

Typically, corrosion protection for steel piles is not considered during design. If corrosion protection is necessary, we recommend increasing the H-pile section to provide an allowance for sacrificial steel. The increase in section can be determined using a corrosion rate of 12 to 15 µm per year over the design life of the structure.

The following design and construction details should be observed for steel piles driven into bedrock. The design and construction details should be considered when preparing the project documents.

1. Preliminary wave equation analysis indicates that an open-ended diesel hammer with a manufacturer's rated energy of 70 to 75 k·ft (such as an APE D30-32 or Delmag D30-32 hammer) may develop a nominal (unfactored) static resistance of 500 to 600 kips, at a driving resistance approaching virtual refusal (10 blows per inch) for AASHTO M 270, Grade 50, HP12x74 and HP14x89 driven steel piles, respectively. The maximum compressive stress induced in the piles during driving is estimated to be below 45 ksi (90% of yield stress for the Grade 50 HP sections). We recommend applying a resistance factor of 0.65 to the nominal static resistance, provided that a number of piles are dynamically monitored with a pile driving analyzer and subsequent capacity estimates (CAPWAP) verify that the nominal resistance was obtained. This work may be completed by an independent engineering firm, with sufficient experience and expertise in collecting and reducing pile stress measurements, working for and paid by the Contractor. The number of monitored piles may be determined by Table 10.5.5.2.3-3, using the recommendations for "high" site variability. If monitoring is not required, then a resistance factor of 0.40 is recommended for the nominal static resistance.
2. Pre-drilling of piles may be required to facilitate pile installation and to achieve the required minimum pile tip elevations.
3. All piles should be protected with commercial driving tips.

4. Drive the steel piles to a driving resistance of 10 blows per inch (virtual refusal) unless indicated otherwise.
5. The pile driving hammer shall be configured to deliver maximum energy at the end of driving unless directed otherwise.
6. The piles should develop a minimum pile embedment below ground surface of 12 ft.
7. Based on the borings to date, It is estimated that pile tips will be as shown in Table 2.

Table 2: Estimated Pile Tips

Boring	**Depth to Water (ft)**	**Total Depth (ft)**	**Estimated Depth to Pile Tip (Ft)**
YA-A1 - South	4	58	50
YA-A2 - North	1	68	30
YA-P1a - Pier	14, *45 frozen*	70	50
YA-P1b - Pier	11, *60 frozen*	50	50

8. The minimum spacing requirements between piles should be three diameters from center to center. For lateral loading, recommended P multipliers are 0.5 for tangent piers increasing linearly to 1.0 for piers placed at 3 diameters or greater. Additional capacity reduction factors can be provided if required for conditions other than those anticipated.
9. A representative of the geotechnical engineer should observe pile driving activities, on a full-time basis. Piles should be observed and checked for crimping, buckling and alignment. Also a record should be kept of embedment depths and penetration resistances for each pile.
10. Driven piles should be installed per Revised Section 502 of the Standard Specifications for Road and Bridge Construction.

LIMITATIONS

This study has been conducted in accordance with generally accepted geotechnical engineering practices in this area for use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon the data obtained from field reconnaissance, exploratory drilling, and the proposed type of construction. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, fill, soil, or water conditions appear to be different from those described herein, this office should be advised at once so reevaluation of the recommendations may be made. We recommend on-site observation of excavations and foundation bearing strata by a representative of the geotechnical engineer.

Respectfully Submitted,

YEH AND ASSOCIATES, INC.

Prepared by:

____

Todd G Hansen, E.I.T.
Project Engineer

Prepared and Reviewed by:

____

Ben P. Arndt, P.E., P.G.
Associate

Reviewed by:

Richard Andrew, P.G.
Principal

APPENDIX A – BORING LOG LOCATIONS

LEGEND

⊕ BORE HOLE LOCATION

ALL LOCATIONS APPROXIMATE

Print Date: $DATE$
File Name: $FILES$
Horiz. Scale: $SCALESHORT$ Vert. Scale: As Noted
Unit Information Unit Leader Initials

Yeh and Associates, Inc.
Consulting Engineers & Scientists

R-X

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
DOT
DEPARTMENT OF TRANSPORTATION
714 Grand Avenue
Eagle, CO 81631
Phone: 970-328-6385 FAX: 970-328-2368
Region 3 PBK

As Constructed
No Revisions:
Revised:
Void:

BORE HOLE LOCATION MAP

Designer: B. Arndt
Detailer: M. Walz
Sheet Subset:
Structure Numbers
Subset Sheets:

Project No./Code
Project Number
Code
Sheet Number

$PLOT_INFO$

APPENDIX B – BORING LOGS AND LEGEND

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **A-1 (South)**
Sheet 1 of 2

Boring Began: 6/12/2009
Drilling Method: Hollow-Stem Auger
Drill: CME 55 Rubber Track
Driller: Precision Sampling
Logged By: T. Hansen
Final By: T. Hansen
Inclination: Vertical

Completed: 6/12/2009
Drill Bit:
Casing:
Weather: windy, cool

Total Depth: 58.0 ft
Ground Elevation:
Location: 39.56469, -106.23672
Coordinates: N: E:

Ground Water Notes:

Depth	∇ 17.0 ft	-	-	-
Date	6/12/09	-	-	-
Time	-	-	-	-

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
	0							**0.0 - 6.0 ft. gravelly SAND FILL** with gravels and cobbles, gray brown, no plasticity, moist to wet, dense, next to ditch.	Bentonite plug 0 ft to 10 ft
	5				15/14/17	31			
	6							**6.0 - 58.0 ft. Landslide COLLUVIUM** ranges from silty sand to sandy clay with gravel, cobbles and boulders consisting of sandstone, shale, and conglomerate, reddish brown, no to medium plasticity, moist to wet, medium dense to very dense, subangular to rounded, coarse grained sand, moderate cement sandstone.	
	10				4/7/7	14		49' F.	MC= 9.3 % #200= 13 % LL= NV PL= NP PI= NP S= 0.006 % AASHTO: A-1-b (0) USCS: SM
	15				22/16/38	54		42' F.	MC= 8.5 % #200= 21 % LL= NV PL= NP PI= NP pH= 8.6 AASHTO: A-1-b (0) USCS: SM
∇	17								
	20				13/24/16	40		50' F.	
	25				9/9/11	20		55' F.	

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **A-1 (South)**
Sheet 2 of 2

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
				RQD	Blows per 6 in	N			
					7/9/13	22			
	35				32/24	56			
	40				15/17	32			MC= 4.9 % #200= 14 % LL= NV PL= NP PI= NP AASHTO: A-1-b (0) USCS: SM
	45				9/8	17			
	50				13/50:5"	50:5"		52' F.	
	55				50:3"	50:3"			
								Bottom of Hole at 58.0 ft.	Auger refusal
	60								
	65								

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **A-2 (North)**
Sheet 1 of 3

Boring Began: 6/11/2009
Drilling Method: Hollow-Stem Auger
Drill: CME 55 Rubber Track
Driller: Precision Sampling
Logged By: T. Hansen
Final By: R. Bartingale
Inclination: Vertical

Completed: 6/11/2009
Drill Bit:
Casing:
Weather: snow, rain

Total Depth: 68.0 ft
Ground Elevation:
Location: 39.56516, -106.23595
Coordinates: N: E:

Ground Water Notes:

Depth	▽ 1.0 ft	-	-	-
Date	6/11/09	-	-	-
Time	-	-	-	-

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
	0							**0.0 - 1.0 ft. Topsoil**.	Bentonite plug 0 ft to 10 ft
▽	1							**1.0 - 2.0 ft. sandy CLAY**, reddish brown, wet.	
	2							**2.0 - 8.0 ft. silty SAND**, reddish brown, no to low plasticity, wet, loose to very loose.	
	5				1/1	2			
	8							**8.0 - 68.0 ft. Landslide COLLUVIUM** ranges from silty sand to sandy clay with gravel, cobbles, and boulders consisting of sandstone, shale, and conglomerate, reddish brown, no to medium plasticity, moist to wet, medium dense to very dense, subangular to rounded, coarse grained sand, moderate cement sandstone.	
	10				6/15(rock)	15(rock)			
	15				6/5	11			MC= 10.5 % DD= 121.3 pcf S= 0.002 %
	20				14/26	40			MC= 11.5 % DD= 125.5 pcf #200= 25 % LL= 29 PL= 16 PI= 13 AASHTO: A-2-6 (0) USCS: SC
	25				7/50:5"	50:5"			

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
					50:3"	50:3"			
	35				22/35	57			
	40				25/27	52			MC= 8 % #200= 15 % LL= NV PL= NP PI= NP AASHTO: A-2-4 (0) USCS: SM
	45				50:4.5"	50:4.5"			
	50				50:2"	50:2"			
	55				50:4"	50:4"			
	60				40/50:2"	50:2"			
	65				50:2"	50:2"			

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **A-2 (North)**
Sheet 3 of 3

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
				RQD	Blows per 6 in	N			
								Bottom of Hole at 68.0 ft.	Auger refusal
	70								
	75								
	80								
	85								
	90								
	95								
	100								

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **P-1a (WB I-70)**
Sheet 1 of 2

Boring Began: 6/5/2009
Drilling Method: Solid-Stem Auger
Drill: CME 55 Rubber Track
Driller: Precision Sampling
Logged By: T. Hansen
Final By: T. Hansen
Inclination: Vertical

Completed: 6/5/2009
Drill Bit:
Casing:
Weather: windy, cool

Total Depth: 50.0 ft
Ground Elevation:
Location: 39.56488, -106.23624
Coordinates: N: E:

Ground Water Notes:

Depth	⊻ 11.0 ft	-	-	-
Date	6/5/09	-	-	-
Time	-	-	-	-

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
	0.0							**0.0 - 0.7 ft. Asphalt Pavement** ~8 inches.	Bentonite plug 0 ft to 5 ft
	0.7							**0.7 - 3.5 ft. gravelly SAND FILL**, reddish brown, no plasticity, damp, medium dense.	
	3.5							**3.5 - 50.0 ft. Landslide COLLUVIUM** ranges from silty sand to sandy clay with gravel, cobbles, and boulders consisting of sandstone, shale, and conglomerate, reddish brown, no to medium plasticity, frozen to damp, medium dense to very dense, subangular to rounded, coarse grained sand, moderate cement sandstone.	
	5	⋈			9/13	22			
	10	⋈			5/5	10			
⊻	11								
	15	⋈			9/10	19			
	20	⋈			9/11	20			
	25	⋈			12/21	33			

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **P-1a (WB I-70)**
Sheet 2 of 2

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
				RQD	Blows per 6 in	N			
					36/34	70			
	35				29/50:6"	50:6"			
	40				50:0"	50:0"			
	45				50:5.5"	50:5.5			
	50							Bottom of Hole at 50.0 ft.	Drill breaks down
	55								
	60								
	65								

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing
Project Number: 29-098 Date:

Boring: **P-1b (WB I-70)**
Sheet 1 of 3

Boring Began: 6/15/2009
Drilling Method: Hollow-Stem Auger
Drill: CME 75
Driller: Precision Sampling
Logged By: T. Hansen
Final By: T. Hansen
Inclination: Vertical

Completed: 6/15/2009
Drill Bit:
Casing:
Weather: thunder

Total Depth: 70.5 ft
Ground Elevation:
Location: 39.56488, -106.23624
Coordinates: N: E:

Ground Water Notes:

Depth	⊻ 14.0 ft	-	-	-
Date	6/15/09	-	-	-
Time	-	-	-	-

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
				RQD	Blows per 6 in	N			
	0.0							**0.0 - 0.7 ft. Asphalt Pavement** ~8 inches.	Bentonite plug 0 ft to 10 ft
	0.7							**0.7 - 7.0 ft. silty SAND FILL** with gravel, reddish brown, no plasticity, damp, medium dense, reprocessed landslide.	
	5				13/11	24		55' F.	
	7.0							**7.0 - 70.5 ft. Landslide COLLUVIUM** ranges from silty sand to sandy clay with gravel, cobbles and boulders consisting of sandstone, shale, and conglomerate, reddish brown, no to medium plasticity, frozen to wet, medium dense to very dense, subangular to rounded, coarse grained sand, moderate cement sandstone. 50' F.	
	10				7/7	14			MC= 5.8 % #200= 9 % LL= NV PL= NP PI= NP pH= 9 AASHTO: A-1-b (0) USCS: SP-SM
	⊻ 14								
	15				7/10	17			MC= 0.5 % S= 0.008 %
	20				7/8	15		40' F.	
	25				9/11	20		42' F.	

YEH AND ASSOCIATES, INC. GEOTECHNICAL ENGINEERING CONSULTANTS	Project: Vail Pass Wildlife Crossing Project Number: 29-098 Date:	Boring: **P-1b (WB I-70)** Sheet 2 of 3

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
					13/19	32		44' F.	
	35				30/33	63		52' F.	
	40				23/50:6"	50:6"		55' F.	MC= 6.5 % #200= 17 % LL= NV PL= NP PI= NP AASHTO: A-1-b (0) USCS: SM
	45				50:5"	50:5"		50' F.	
	50				8/20	28			
	55				20/50:6"	50:6"		45' F.	
	60				12/30	42		28' F.	
	65				25/50:4"	50:4"		18' F.	

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Vail Pass Wildlife Crossing

Project Number: 29-098 Date:

Boring: **P-1b (WB I-70)**

Sheet 3 of 3

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
				RQD	Blows per 6 in	N			
	70				50:1"	50:1"		Bottom of Hole at 70.5 ft.	Auger refusal
	75								
	80								
	85								
	90								
	95								
	100								

APPENDIX C – LABORATORY TEST RESULTS

YEH & ASSOCIATES, INC

Summary of Laboratory Test Results

Project No: 29 - 098 Project Name: Vail Wildlife Crossing Date: 6/22/2009

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate %	% Swell (+) / Consoli-dation (-)	Unconf. Comp. Strength (psf)	R-VALUE	CLASSIFICATION	
Boring NO.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI						AASHTO	USCS
A - 1	10	CA	9.3	–	40	47	13	NV	NP	NP	–	0.006	–	–	–	A-1-b (0)	SM
A - 1	15	CA	8.5	–	15	64	21	NV	NP	NP	8.6	–	–	–	–	A-1-b (0)	SM
A - 1	40	CA	4.9	–	39	47	14	NV	NP	NP	–	–	–	–	–	A-1-b (0)	SM
A - 2	15	CA	10.5	121.3	–	–	–	–	–	–	–	0.002	–	–	–	–	–
A - 2	20	CA	11.5	125.5	22	53	25	29	16	13	–	–	–	–	–	A-2-6 (0)	SC
A - 2	40	CA	8.0	–	13	72	15	NV	NP	NP	–	–	–	–	–	A-2-4 (0)	SM
P - 1	10	CA	5.8	–	5	86	9	NV	NP	NP	9.0	–	–	–	–	A-1-b (0)	SP - SM
P - 1	15	CA	0.5	–	–	–	–	–	–	–	–	0.008	–	–	–	–	–
P - 1	40	CA	6.5	–	2	81	17	NV	NP	NP	–	–	–	–	–	A-1-b (0)	SM