APPENDIX A18

GEOLOGIC RESOURCES AND SOIL TECHNICAL MEMORANDUM

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Geologic Resources and Soil Technical Memorandum

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Introduction and Background

The Interstate-70 (I-70) West Vail Pass Auxiliary Lanes project is located in Eagle and Summit Counties, with the eastern terminus just east of the Vail Pass Rest Area and the western terminus in the Town of Vail. The project study limits include eastbound (EB) and westbound (WB) I-70 corridor from mile post (MP) 179.5 to MP 191.5, including the Vail Pass Recreation Trail. The project location and approximate study area are shown in **Figure 1**.

As part of the initial National Environmental Policy Act (NEPA) analysis, a Tier 1 Environmental Impact Statement (EIS) for the I-70 Mountain Corridor (C-470 to Glenwood Springs) was completed in 2011. This EIS, the *I-70 Mountain Corridor Programmatic Final Environmental Impact Statement* (PEIS), recommended the addition of auxiliary lanes EB and WB on the west side of Vail Pass from MP 180 to MP 190 as part of the Preferred Alternative's Minimum Program of Improvements. The PEIS also identified the potential for an elevated Advanced Guideway System (AGS) for transit along the I-70 corridor, including the West Vail Pass project corridor. A follow-up AGS Feasibility Study in 2014 analyzed potential alignments and costs for an AGS system and determined there were three feasible alignments for future AGS. While AGS is not part of the West Vail Pass Auxiliary Lanes project, the AGS Feasibility Study was used to ensure the project did not preclude the favored alignment of the three, which would be partially within CDOT right-of-way (ROW).

A Tier 2 NEPA analysis is the next step required to move highway improvements forward. The project is following the Colorado Department of Transportation (CDOT) and Federal Highway Administration (FHWA) NEPA process to confirm the needs for improvements to the West Vail Pass, identify a Proposed Action, investigate the anticipated benefits and impacts of the proposed improvements (through an Environmental Assessment), produce conceptual design plans, and make funding, scheduling, and phasing recommendations.

This section discusses the existing conditions and potential impacts of the project alternatives related to geologic resources and soil. The study area for geology includes the regional geology, surficial deposits (soils), geologic hazards and historic mining activity that are near, underlie, or are located along the project corridor. The mitigation measures identified at the end of this memo are consistent with the mitigation strategies identified in the *I-70 Mountain Corridor Record of Decision*.

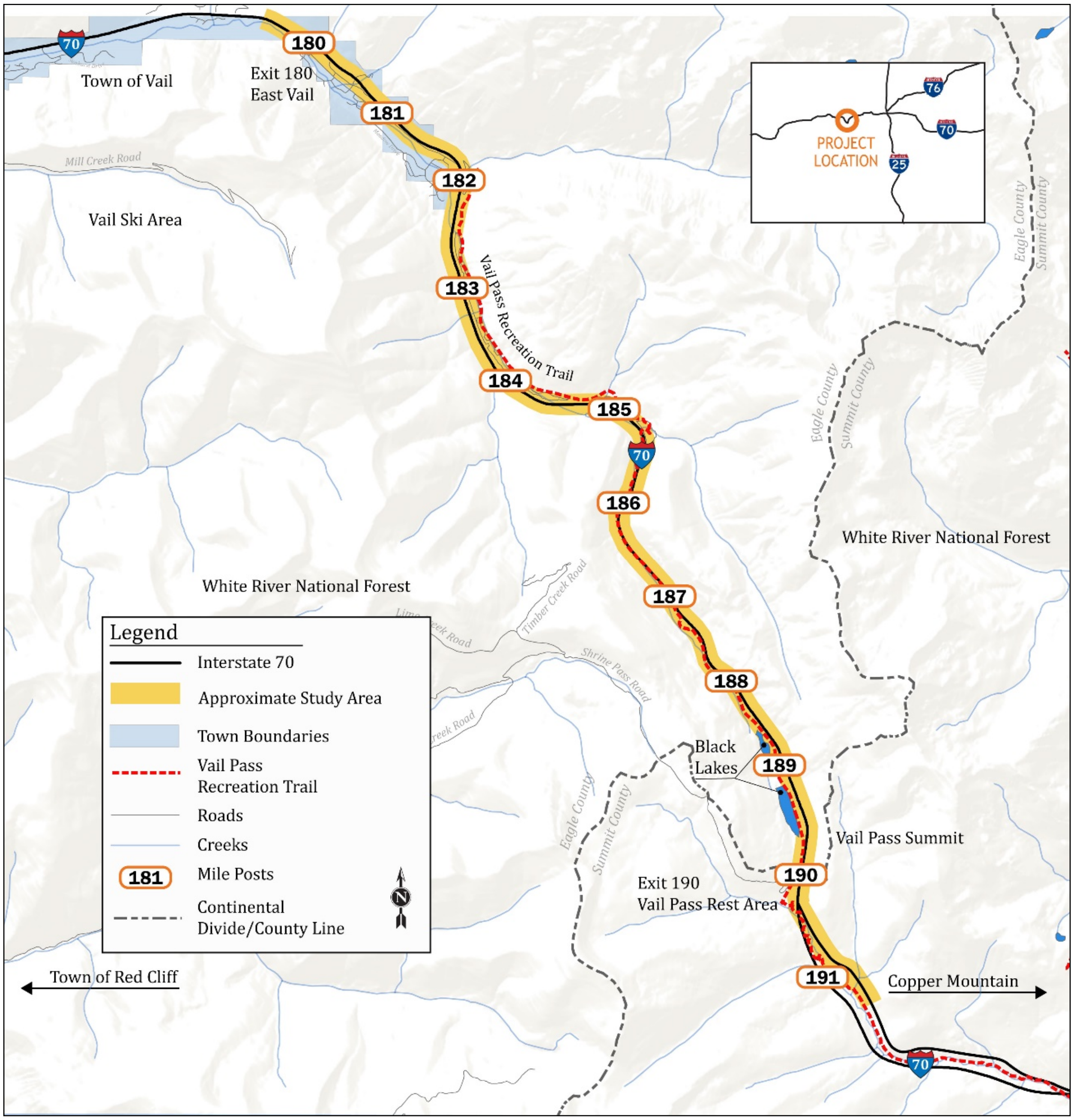
Legislation

There is very little adopted policy that pertains directly to geology, soils and geologic hazards. Most counties and municipalities have adopted geologic hazard ordinances, requiring the identification proposed mitigation alternatives be developed as part of the construction. These ordinances more specifically pertain to residential and commercial construction as required by HB 1041 and SB 35. (Noe, 1998)

Study Area

The length of the study area for the Geologic Resources extends along the project limits from MP 179.5 to MP 191.5 and the width was bound from ridgeline to ridgeline of the Black Gore Creek and Gore Creek drainage basins.

Figure 1. Project Location and Study Area



Source: DEA Project Team

Purpose and Need

The purpose of the project is to improve safety and operations on EB and WB I-70 on West Vail Pass.

This project is needed to address safety concerns and operational issues due to geometric conditions (steep grades and tight curves) and slow-moving vehicle and passenger vehicle interactions that result in inconsistent and slow travel times along the corridor. The I-70 Mountain Corridor Programmatic Environmental Impact Statement (PEIS) identified safety and mobility issues on West Vail Pass related to speed differentials due to slow-moving vehicles. *(Mobility is defined as the ability to travel along the I-70 Mountain Corridor safely and efficiently in a reasonable amount of time.)*

- Safety Concerns: A high number of crashes occur along the corridor related to speed, tight curves, narrow roadway area, and inclement weather/poor road conditions. Speed differentials between passenger vehicles and slow-moving vehicles cause erratic lane changes and braking maneuvers resulting in crashes and spin outs. Emergency response is hampered by vehicular speeds and lack of roadway width to provide room for emergency vehicles to pass.
- Operational Issues: The steep grades and resulting speed differentials causes slow and unreliable travel times through the corridor. Tight curves also cause drivers to slow down. The corridor is frequently closed by vehicle incidents, due to lack of width to maintain a single lane of traffic adjacent to emergency responders, resulting in substantial traffic backups and delays. During winter months, the travel lanes and shoulders are severely impacted by snow accumulation, impacting the overall capacity of the corridor. *(Operations is intended to describe the flow of traffic at desirable speeds given the geometric and prevailing weather conditions.)*

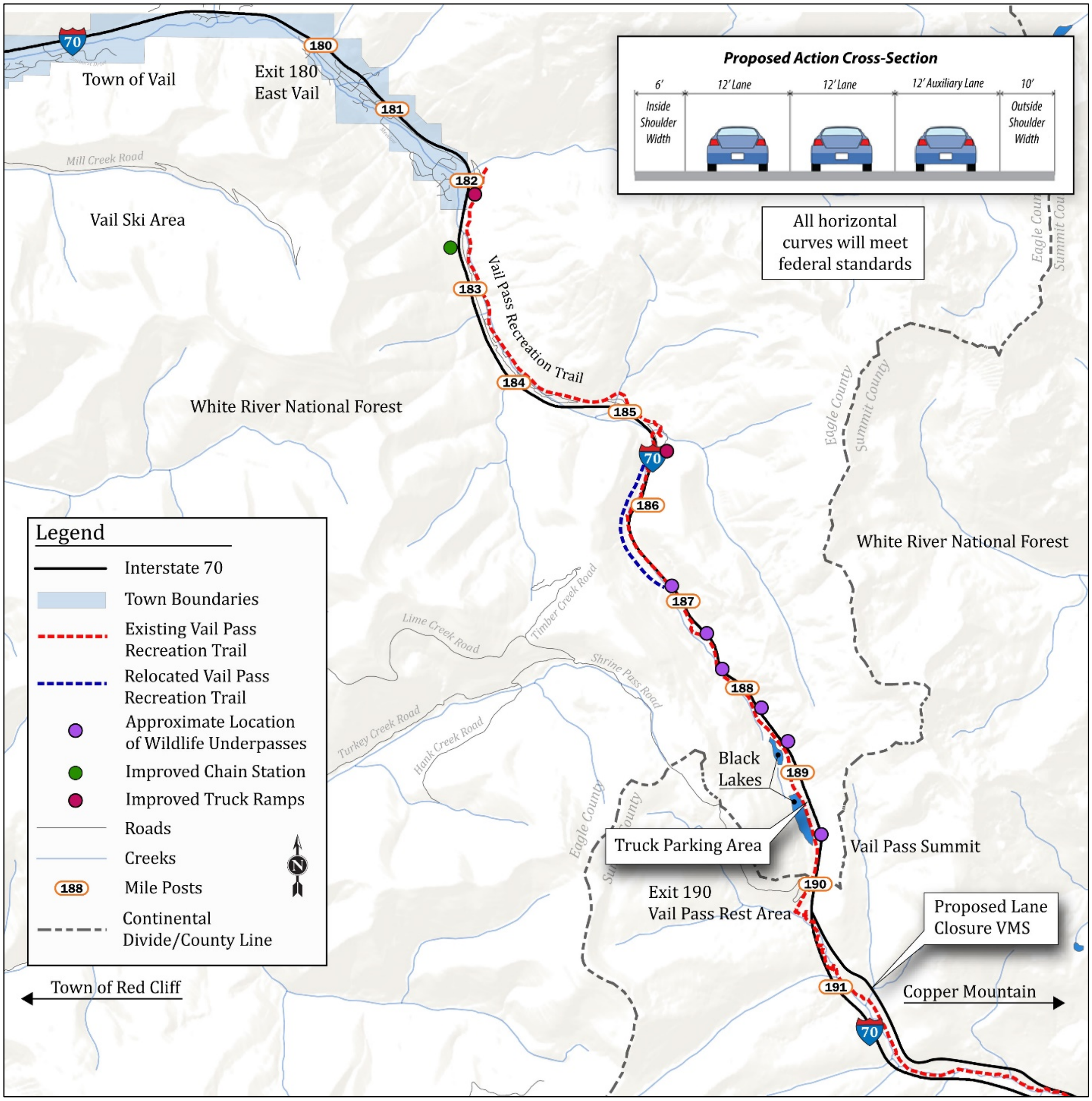
No Action Alternative

The No Action Alternative is included as a baseline for comparison to the action alternative. Under the No Action Alternative, only programmed projects that are planned and funded by CDOT or other entities would be completed. Currently, there are no large-scale transportation projects to add safety improvements, operational improvements, vehicular capacity, and multimodal facilities along I-70 within the project area. The No Action Alternative would leave West Vail Pass as it currently is configured and would not provide substantial improvements beyond typical current maintenance (e.g. resurfacing and plowing) activities. The roadway would remain the same, with 2 EB and 2 WB lanes (each 12 feet in width), an inside shoulder typically 4 feet in width, and an outside shoulder typically 10 feet in width.

Proposed Action Alternative

The Proposed Action (**Figure 2**) will add a 12-foot auxiliary lane, both EB and WB, for 10 miles from approximately the East Vail exit (MP 180) to the Vail Pass Rest Area exit (MP 190). Existing lanes will be maintained at 12 feet and the shoulders would be widened to a minimum of 6 feet for inside shoulders and maintained at 10 feet for outside shoulders. All existing curves will be modified as needed to meet current federal design standards.

Figure 2. I-70 West Vail Pass Auxiliary Lanes Proposed Action Alternative



Source: DEA Project Team

Intelligent Transportation System (ITS) equipment will also be installed along the I-70 project corridor, consistent with recent study recommendations. Additional variable message signs (VMSs) will be installed at key locations to warn drivers of upcoming curves, grades, and incidents. Additional variable speed limit signs will be installed to manage driver speeds to conditions. Automated lane closure signage will be installed approaching the East Vail exit on EB I-70 and approaching the WB I-70 Vail Pass Rest Area exit to quickly and efficiently close lanes when needed.

Additional elements of the Proposed Action include:

- The Vail Pass Recreation Trail will be directly impacted by the addition of the I-70 auxiliary lane and therefore relocated for approximately two miles from MP 185 to MP 187.
- Existing emergency truck ramps, located at approximately MP 182.2 and 185.5, will be upgraded to current design standards.
- Six wildlife underpasses and wildlife fencing will be constructed throughout the corridor.
- Additional capacity will be added to the existing commercial truck parking area at the top of Vail Pass.
- Widened shoulders (minimum of eight feet of additional width beyond the 10’ shoulder) at multiple locations to accommodate emergency pull-offs, emergency truck parking, and staging for tow trucks.
- Improved median emergency turnaround locations to accommodate emergency and maintenance vehicle turnaround maneuvers.
- Improved chain station located at approximately MP 182.5 with additional parking, signage, lighting, and separation from the I-70 mainline.
- Avalanche protection located at approximately MP 186.

Methodology

Geologic conditions present within the project area were identified using information from geologic maps, U.S. Geological Survey reports, Colorado Geological Survey publications, topographic maps, Light Detection and Ranging (LiDAR) mapping, and previous reports regarding as-built construction of Interstate 70 (I-70) in the project area, with field verification of some mapped features in accessible areas. In 2016, 2008 LiDAR data from Eagle County, Colorado Geographic Information System (GIS), 1998 2-foot contour mapping, and other imaging, was compiled to model conditions in the project area.

The NRCS and USFS have published maps and reports on the soil erosion potential in the study area. NRCS provided soil descriptions, characteristics, and modeling factors. U. S. Forest Service provided erodibility descriptions and management considerations. Both agencies characterize soil types as slightly, moderately, or severely susceptible to erosion.

Existing Conditions

This section summarizes an initial evaluation of the geologic, geologic hazards and soils resources posed by the natural and human-made setting within the vicinity of the West Vail Pass I-70 widening project, which includes the area of the interstate between East Vail interchange and Vail Pass Summit. The elevation of the interstate in the widening project area varies between approximately 8,250 and 10,670 feet.

General Geology

The most prominent geologic features of the Vail Valley area are the extensive landslides. The two types of landslide described in the study area occur either in the surficial deposits or deeper into bedrock. The bedrock of the valley is Pennsylvanian to Permian age sedimentary rock of the Minturn and Maroon formations that include conglomerate, sandstone, siltstone, shale, and limestone beds.

These were deposited on older igneous and metamorphic rocks, including gneissic granite and migmatite of Precambrian age that forms the core of the Gore Range. Bedrock is exposed in outcrops and cut slopes. Surficial deposits range from a few inches to more than 90 feet thick and include clay, silt, sand, gravel and boulders derived from fluvial and glacial processes, and weathering of the bedrock. Four specific types of surficial deposits found in the study area include glacial, alluvial, colluvial, and residuum. References for information regarding geology in this report, including geology maps, can be found in the References section at the end of this report.

Bedrock Formations

The sedimentary bedrock in the study area has been mapped by others as the Pennsylvanian age Minturn Formation and the Pennsylvanian-Permian age Maroon Formation. In areas of the Gore Range, these formations were deposited onto the Precambrian rock base during the uplift of the Ancestral Rocky Mountains and can be a few feet to 1,000 feet thick.

The lithologic units in the Minturn and Maroon formations are similar in color and type and include conglomerate, sandstone, siltstone, and shale that can be grayish-red, pale reddish brown, orange red, or maroon. Most of the sandstones and conglomerates are arkosic, micaceous and poorly sorted with clasts up to cobble size with poor cementation. The siltstone and shale are micaceous, and poorly cemented, and weather into a soft micaceous soil. There are pale gray, fossiliferous, limestone beds in the Minturn Formation that include casts of shells of fusilinids, gastropods, brachiopods, and crinoid stems.

Precambrian age rocks include granite and migmatite. The gneissic granite ranges in composition from a biotite-quartz diorite to a biotite granite. Most of the rock is a biotite granodiorite or quartz monzonite, while inclusions of metasedimentary rock in the granite are common. These inclusions are mostly biotite-quartz-plagioclase gneiss and schist, and biotitic quartzite.

The migmatite consists of alternating light and dark mineral layers, ranging from less than an inch to several inches thick that have been highly folded and contorted. The migmatite is generally believed to have been formed from pre-existing Precambrian sedimentary rocks as a result of deep burial where extreme heat and pressure caused partial melting of the original rock, mineral segregation, plastic flow, with later intrusions of granitic magma.

Faults and Seismicity

The study area is not considered to be seismically active. There are no known active faults either on or adjacent to the I-70 corridor along Vail Pass, and the potential for surface fault rupture is low. In the project area, the Gore Range Fault Zone has been mapped by U.S. Geological Survey (Kellogg, 2003).

Surficial Deposits (Soils)

Glacial deposits of till and stratified drift were formed as glacial ice scoured the existing surface and created poorly sorted, clay, silt, sand, cobbles and boulders during numerous cold and warm climatic cycles. Till that forms hummocky moraine features are the most abundant types of surficial deposits in the area and have subsequently been altered by fluvial and colluvial erosion and deposition. Glacial deposits range from a few feet to over 90 feet thick in the study area.

Alluvial deposits occur in the valley floors of the major streams with alluvial fans occurring only where stream flow is intermittent. The alluvium generally consists of well sorted and stratified gravel, sand, and silts, and can range from a few feet to up to 50 feet thick. The gradient of a drainage determines the average particle size deposited. Terrace deposits represent stream levels at previous periods of erosion or at higher flood plain levels. Terrace deposits generally consist of well-sorted and stratified gravel, sand, and silt and can range between 5 feet to 20 feet thick. Some of these deposits may have been created behind ice dams.

Colluvial deposits develop from gravity induced movement of rock downslope. Deposits of colluvium generally range in particle size from silt to boulders up to 4 feet in diameter. The thickness of the deposits is dependent on slope angle and weathered rock available to move downslope. These deposits range from less than 1 foot to 25 feet thick.

Residual deposits include swamp deposits and boulder trains. Swamps are undrained depressions that collect stagnant water at or near the surface. Swamps are likely to be found on glacial deposits, but also develop on landslides, and range in size from only a few feet in area to thousands of feet long when bordering streams. Typical swamp deposits of organic rich mud and peat are found in the larger swamps, while smaller swamp deposits consist of organic, sandy silt up to 5 feet thick. Alluvium can also be deposited as boulder trains, which are concentrations of rounded clasts in long bands at right angles to the valleys, generally found on glacial deposits. Boulder trains are considered to be a result of temporary, but high velocity, glacial outwash streams running down the valley walls, depositing only large clasts that can be up to 8 feet in diameter, and washing out remaining fines.

Groundwater

Based on the Transportation Research Board (TRB, 1979), and Robinson (1971), most groundwater in the Vail Pass area travels through the surficial deposits, with some water flowing in fractures and zones of porosity in bedrock. Areas of surface and near-surface groundwater have been mapped. Springs were noted at the edges of surficial deposits, including surficial and bedrock landslide areas. During field mapping for this report, seeps were noted in surficial deposits in drainages, at toe of landslide areas, at the base of fill slopes, and in bedrock between sedimentary layers. Based on data from observation wells used in studies for the original construction of I-70 at West Vail Pass, groundwater levels, in general, peaked in late spring and early summer (Robinson, 1971). In August 2016, groundwater monitoring data in the area of MP 186 indicated groundwater levels at 4 to 12 feet below ground surface (CDOT, 2016).

Variations in groundwater conditions may occur seasonally. The magnitude of the variation will be largely dependent upon the amount of spring snowmelt, duration and intensity of precipitation, irrigation practices, site grading changes, and the surface and subsurface drainage characteristics of the surrounding area. Perched water tables may be present and is dependent on localized geologic conditions.

Geologic Hazards

Geologic hazards are defined as natural phenomena, or a geologic process, capable of inflicting harm to people or property (USGS, 2017). The varied and complex geology and geomorphic processes in the Vail Valley has led to the development of the several zones of instability and marginally stable subsurface material. Although these are the result of natural processes, these conditions can pose a risk to people either directly by an encounter with the hazard or indirectly through effect of the hazard on roadways, railways or buildings. The geologic structure, slope configuration, precipitation, wind, and extreme temperature fluctuations all contribute to geologic hazards within the project area. Effects produced by the climate on soil and rocks include wetting and drying, precipitation, freeze-thaw, and snowmelt. Vail Valley slopes, especially those with little vegetation cover, can be highly susceptible to erosion. Geologic hazards that may adversely affect people and/or the proposed improvements in the West Vail Pass corridor include, but are not limited to, landslides, debris flow, rockfall, frost heave, and avalanches.

LANDSLIDES

Landslides include the movement of both competent material as rockslides and incompetent material as debris slides (TRB, 1996). Debris flows and rockfall are subcategories of landslides, but for clarity, will be included in separate discussions based on differing modes of failure. Landslides are distinguished from debris flows by the method and means for transport of the material downslope. Unlike flows, slides occur along a defined slip surface, and usually have a defined scarp at the head forming a step like appearance. The main scarp is a steep surface at the upper edge of a landslide where displaced material has moved away from undisturbed ground.

About 50 percent of I-70, between the west portion of the Town of Vail and the summit of Vail Pass was built on existing landslides. Older slides that generally involved the bedrock of the Minturn Formation, Maroon Formation, or less frequently, igneous and metamorphic rock, are more stable than the younger, more active slides in surficial deposits. Surficial deposits in landslides are generally glacial deposits and/or colluvium. (TRB 1979). Thick-bedded sandstone and less competent mudstone layers of the Minturn Formation are susceptible to sliding, although slides can occur in other areas where there are oversteepened slopes (Kellogg, et al, 2003).

DEBRIS FLOWS

As defined by the Colorado Geological Survey, debris flows are a combination of fast-moving water, sediment and debris that surges down slope with tremendous force (CGS-Debris Flow). For this report, mudslide, or mudflow, which are similar to debris flows, but with mostly fine-grained material in rapid flow, have been categorized with debris flows. Debris flows are rapidly deposited in and along high barren mountain drainage basins. Debris flows are a subcategory of landslides that can occur in landslide deposits. Alluvial fans can develop where debris flows exit drainages. Debris and alluvial fans may present problems for construction due to voids in the deposits, which can result in collapsible soils (CGS Collapsible Soils).

ROCKFALL

Most of the rockfalls within the project limits occur in rock outcrop areas of steep slopes and cliffs. Weak shale beds in sedimentary rock layers, joints, or separations, in rock outcrops, and rock layers dipping, or tilted, toward the roadway can cause rockfall hazards. In addition, repeated freeze-thaw cycles tend to dislodge rocks from cliffs (Kellogg et al, 2011). While some rockfall may be rock that detaches from a larger rock mass, rocks, up to boulders in size, in rocky soils, such as surficial glacial deposits, can also be mobilized from steep slopes (CGS, Rockfall).

FROST HEAVE

Based on the CDOT 2016 report on I-70 Vail Pass Frost Heave, frost heaves occur when segregated ice forms in soil resulting in upward movement of the ground surface. Frost heaves typically develop in shallow frost susceptible soils that have available water in prolonged freezing conditions. Aggregate road base generally is considered a frost susceptible soil. Poor drainage conditions or surface infiltration of water can also be contributing factors. Frost heave repairs have been undertaken near MP 186 on I-70 (CDOT, 2016).

AVALANCHES

Avalanches occur when a large mass of snow, ice, and debris moves rapidly down a mountain slope, generally with a gradient between 25 to 50 degrees (CGS-Avalanche; Mears, 1992). Avalanche chutes appear as elongate, narrow, barren scars, or predominately vegetated with quick-growing trees and shrubs, on a mountainside normal to the strike of the valley. Often, a fan-shaped deposit of alluvial material and/or wood debris is found at the base, or runout zone, of an avalanche chute. Other avalanches can form during periods of high wind causing the rapid accumulation of snow, generally as slabs, which can break off in large sheets (Wind Slab) as found along the Narrows portion of Vail Pass near MP 186.

GEOLOGIC CONDITIONS ALONG I-70, WEST VAIL PASS

For the purposes of discussion, the corridor has been broken into discrete segments that have defined geologic conditions that occur within those segments of the I-70 roadway. The geographic limits of each segment are given by mile post. The information presented in this report was obtained from information and data gathered during the I-70 Programmatic Environmental Impact Study (PEIS), the geotechnical investigation conducted by the Colorado Department of Highways for the original I-70 Interstate project (Robinson, 1971, 1979, 1983), LiDAR data compiled in 2016, and field verification of representative areas by Yeh and Associates for this report. The figures presented below are taken from these referenced reports and data and describe the geologic hazards along the subject corridor. These areas are mapped on the Vail Pass Geohazard Map(s), Plates 1 through 14 included with this report. The geologic hazards identified during the initial study present the same challenge for future highway improvements as they did for the original Vail Pass construction. **Figure 3** depicts the general location of each major geologic hazard along the west side of Vail Pass and **Table 1** presents a summary of the major geologic hazards by mile post.

Figure 3. Approximate Locations of Major Geologic Hazards Along I-70, West Vail Pass

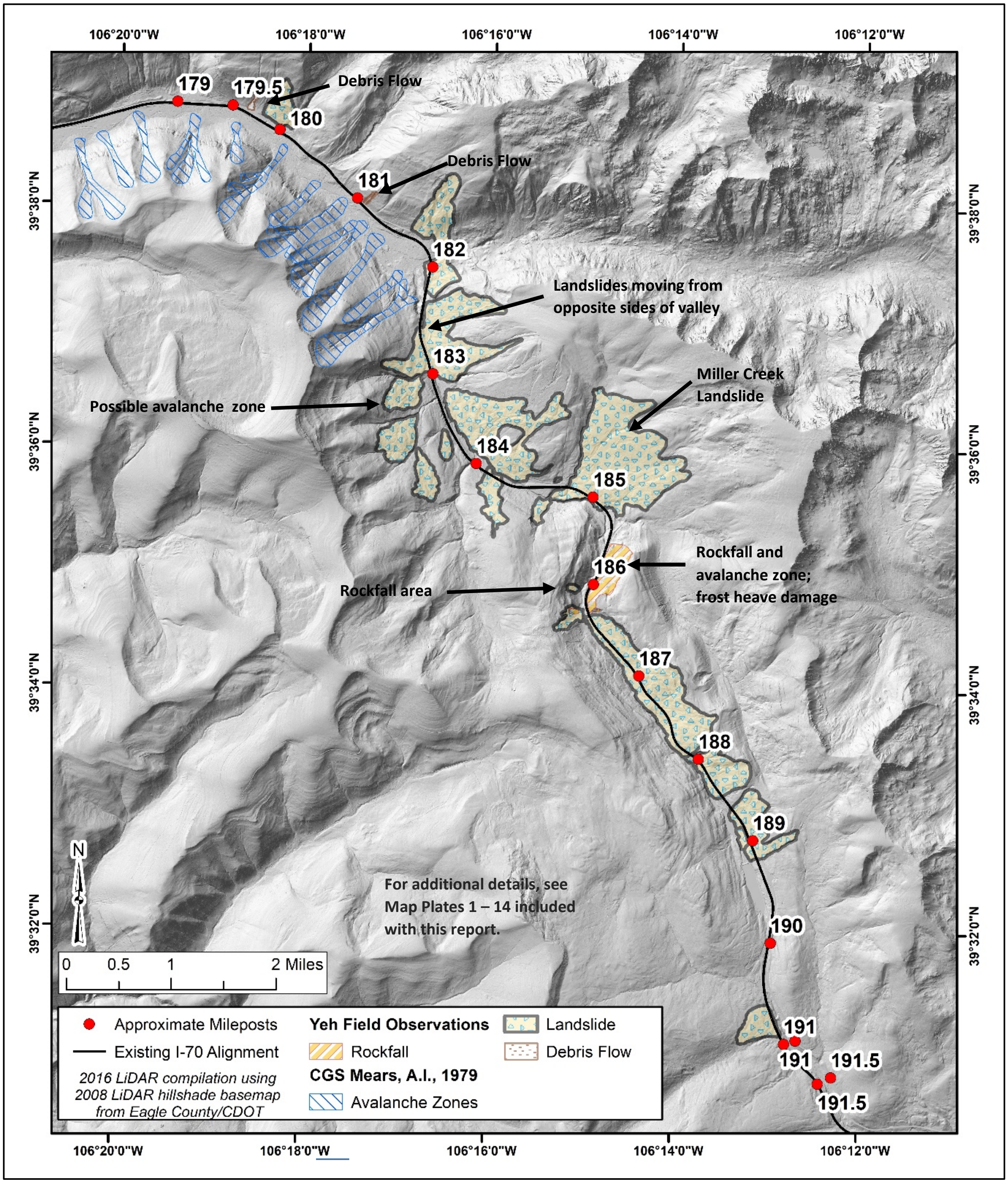


Table 1. Summary of Major Geologic Hazard Areas on West Vail Pass

Approximate Mile Post/ Lane	Description
179.0 to 183.0/East	Avalanche zones and possible avalanche paths mapped by Mears and Robinson; with areas field verified. Alluvial/debris fans at mouths of possible debris flow channels.
179.0 to 179.8/West	Alluvial fan MP 179 to 179.3; Possible avalanche paths field mapped.
179.6 to 179.7/West	Field and LIDAR mapped debris flow feature
179.8 to 180.1/West	Field and LiDAR and mapped landslide features; also mapped by others as landslide area
180.2 to 180.3/West	Field and LiDAR mapped hummocky terrain. Possible disturbed glacial deposits
180.3 to 180.5/West	Field and LiDAR mapped hummocky terrain. Mapped by others as glacial deposits
180.5 to 180.6/West	Alluvial fan deposits at roadway intersection with Big Horn Creek
180.6 to 181.1/West	Mapped by others as unconsolidated glacial deposits; Mapped for original construction of I-70 as "no cut zone" with reduced factor of safety
181.1 to 181.2/West	Field and LIDAR mapped debris flow features
181.2 to 181.6/West	Field and LiDAR mapped hummocky terrain. Mapped by others as glacial deposits
181.6 to 181.7/West	Field and LiDAR and mapped landslide features; also mapped by others as landslide area
181.7 to 181.9/Both	Field and LiDAR mapped alluvial fan deposits
181.9 to 182.2/West	Field and LiDAR mapped landslide south of campground, also mentioned as stabilized bedrock landslide in TRB 717 report
182.2 to 182.5West	Field and LiDAR mapped landslide with thick tree cover
182.5 to 183.0/Both	Buttressing landslides moving from opposite sides of valley; LiDAR and field mapped, mentioned in both Robinson I-70-2 (19) and TRB 717 reports; pavement damage in paved bike path
182.5 to 182.7/West	Impermeable, stepped gabion walls in Black Gore Creek
182.9 to 183.1/West	Smaller localized failures within larger bedrock landslide with pavement damage to bike path in area
183 to 183.8/East	Possible bedrock landslide complex mapped from LiDAR only. Field verification required.
183.2 to 184.0/West	Field and LiDAR mapped landslide in glacial deposits with hummocky terrain; pavement intact on bike path; in area of lake deposits per TRB 717 report

Approximate Mile Post/ Lane	Description
183.6 to 183.8/East	Field and LiDAR mapped landslide area
184.0 to 184.2/Both	Field and LiDAR mapped glacial deposits south of Black Gore Creek; landslide in area of bike path north of interstate
184.2 to 184.4/Both	Field and LiDAR mapped as landslide, and mapped by others as bedrock landslide; tilted bedrock where rock outcrops near I-70; mapped as active in 1977; retaining wall on north side of interstate
184.4 to 184.6/West	Field and LiDAR mapped landslide; hummocky terrain with pavement intact on bike path; mapped as landslide by others and listed as landslide in TRB 717 report
184.8 to 184.9/West	Field and LiDAR mapped landslide adjacent to north side of bike path north of interstate
184.9 to 185.3/Both	Field and LiDAR mapped landslide; Miller Creek landslide complex; LiDAR recon appears to be different than what was originally mapped by the USGS
185.3 to 186.3/East	Steep to very steep slopes greater than 30% grade, some with heavy tree cover, where bike path alignments are proposed
186.1 to 186.2/East	Field mapped landslide area in steep slopes where bike path alignments are proposed
185.5 to 186.3/West	Mapped by others as rockfall zone with soil cover of glacial deposits, refined on LiDAR, and verified in field. Soil cover susceptible to erosion. Area of repaired frost heave damage in pavement near MP 186 (CDOT, 2016)
185.9 to 186.2/East	Possible avalanche path zone field mapped.
186.0 to 186.3/West	Avalanche zones identified in Engineerisk report and by others.
186.3 to 186.4/East	Field and LiDAR mapped as landslide area
186.3/East	Field mapped rockfall zone observed in area of proposed bike path alignments
186.4 to 188.5/Both	Field and LiDAR mapped landslide area with hummocky topography; landslide area mentioned in Robinson I-70-2 (19) report
186.6 to 187.2/East	Steep slopes, with some greater than 30% grade, southwest of and below I-70 in area of proposed bike path alignments; upper portion of steep slope has rills and gullies and may be oversteepened fill.
187.3 to 188.1/East	Steep slopes below interstate with rills and gullies. Seep areas located between I-70 and bike path. May be oversteepened fill on landslide deposits.
188.6 to 189.2/Both	Landslide identified in field and LiDAR mapped. Also mapped in Robinson I-70-2 (19) report
188.8 to 189.0/East	Steep slopes SW of and below interstate with rills and gullies. May be oversteepened fill on landslide deposits.
189.5 to 189.8/East	Steep slopes, with some greater than 30% grade, SW of and below I-70; upper ortion of steep slope has rills and gullies and may be oversteepened fill.
190.9 to 191.1/East	Landslide mapped in Robinson I-7—2 (19) report.

Debris Flow Deposits

Debris flow features were mapped at approximately MP 179.6 on slopes adjacent to the WB lanes of I-70 to the northeast. Other areas of debris flow may exist overlying landslides where alluvial fans are present. Alluvial and debris fans can form at the mouths of steep channels, where the flatter gradient slows the flow and soils and debris are rapidly deposited. Debris flow fans/alluvial fans also are mapped on the east and west side of I-70 between MP 179 and MP 183 at the mouths of possible debris flow channels. The debris flows that have occurred along the corridor are typically caused by infrequent climatic conditions and/or following forest fires. Debris flows can also be found at the toe of a landslide during periods of sudden and rapid movement. Collapsible soils are a typical geohazard associated with these rapidly deposited soils (CGS Collapsible Soils).

Potentially Unstable Slopes

Steep slopes of gravel deposits, generally of glacial origin and steep slopes of fill material present areas of potentially unstable slopes. These areas have been mapped on Map Plates 1 through 14. One area of concern was mapped during the original construction of I-70 at approximately MP 180.6 to 181.1, as potentially unstable slopes above the WB lanes of I-70. Up to 140 feet of unconsolidated glacial deposits with a near-surface water table were encountered during the investigation for the construction of the interstate. The glacial deposits are sand overlain by gravel and boulders with organic layers. For the original I-70 construction, a side-hill viaduct design rather than a cut/fill alternative was chosen due to the marginal stability of the slope and existing residential development near the site. In addition, poorly compacted fill areas could contribute to settlement and increased instability in slopes.

Landslides

Several landslides have been mapped along the interstate in the project area at locations as shown on **Figure 3** and in **Table 1**. During the original geotechnical investigation for the interstate, two active landslides were identified that move from opposite sides of the valley and merge at Black Gore Creek located between MPs 182.5 and 183.0. During construction, a large buttress, constructed of rock-filled wire baskets, was installed along the creek to slow the movement of the two slides. The buttress was placed in the creek, raising the stream channel so that the slides could push against each other. An impoundment was created upstream from the buttress and a rundown, or waterfall, was constructed on the downstream portion of the feature. The run-down included stepped gabion walls with deep foundations to act as cutoff walls, and post-installation grouting was used to reduce permeability through the rock baskets.

Additionally, an active landslide was identified during the 1977 geotechnical investigation at approximately MP 184.2 to MP 184.4 on the east-northeast side of Black Gore Creek. The final I-70 alignment was moved to the west-southwest side of the creek to avoid the landslide.

Reportedly, the most difficult and challenging geotechnical area during the original investigation of the interstate corridor for west Vail Pass was the Miller Creek Slide located from approximately MP 184.9 to 185.3 (TRB, 1979). Estimated to be over 3,000 feet long and 3,000 feet wide, with a depth of about 150 feet, the slide consists of up to 70 feet of surficial silty soils overlying approximately 80 feet of failed bedrock. At the time of the original investigation prior to construction, water levels were erratic, varying from surface ponds in some areas to dry in other areas. Historic movement was indicated by an approximate 1,000-year old buried soil horizon. The slide was stabilized with a high, vertical reinforced earth wall and groundwater levels were lowered by a series of horizontal drains. Shear zones with water flowing up to 200 gallons per minute were encountered during construction.

Between approximately MPs 185.5 to 189.2, bedrock slide and failure areas identified on both sides of the interstate in previous reports (TRB, 1979, and Robinson, 1971), were identified using LiDAR, and field confirmed by Yeh where accessible during this assessment. The slide area between MPs 188.6 to 189.2 was identified previously as very active locally (TRB, 1979). During construction, cuts in these areas initiated a slide that was stabilized during construction. Several water seeps were noted west of the interstate in this area.

Rockfall

Throughout the highway system in western Colorado, there are numerous sites that generate rockfall and pose a potential hazard to the traveling public. The Colorado Rockfall Hazard Rating System (Andrew, 1994) was developed to evaluate the rockfall sites located along the state's highways. Two of the sites that were identified in the 1994 study are located on Vail Pass along I-70. At one of the sites, rockfall originates from a large bench cut through the Maroon Formation on the east side of the interstate (Bergendahl, 1969) in the area between MPs 185.5 to 186.3. Softer claystone seams weather at a faster rate than the thicker sandstone layers initiating rockfall. The erosional process is facilitated by the numerous seepage points along the steep rock face, and by freeze/thaw cycles that accompany the extreme weather conditions encountered at the elevation in the project area. This differential weathering creates undercutting of the sandstone layers leading to destabilization and ultimately results in the toppling of the sandstone blocks. Benches along the slope create launching features, which allows many of the falling rocks to bounce over the rockfall ditches and onto the roadway. In addition, rocks that collect in the ditches can become launch points for falling rock.

Avalanches

The area of the rockfall zone at MP 186.0 to 186.3 has also been the location of numerous snow avalanches (slab avalanches) caused by high winds and heavy snow accumulations. The avalanches have been known to carry large boulders and other debris. Avalanche paths have been mapped south and west of the interstate from the western end of the project area east to approximately MP 183.0, and on the north side of the interstate near MP 179.5 (Mears, 1979). A possible avalanche path was mapped on the west side of the interstate near MP 183.0 (Robinson, 1971). Additional possible avalanche paths identified in the project area during the field mapping for this assessment were located on the west side of the interstate at approximately MPs 182.5, 185.9, and 186.2. During winter months, Colorado Department of Transportation (CDOT) monitors and conducts avalanche control for known avalanche paths that may impact highways (CDOT, Avalanche and Engineerisk, 2015).

Soil Conditions

The soils from the beginning of the study area at MP 180 to approximately MP 183 have moderate susceptibility to erosion on sandstone bedrock or glacial till with slopes ranging from 25 to 65 percent. These areas exhibit a moderate erosion hazard. From MP 183 to the summit of Vail Pass the soils are generalized as the Scout family-Rock outcrop-Hechtman family complex on 40 to 150 percent slopes, characterized as extremely bouldery, and are mostly derived from sandstone bedrock with some Scout family material derived from glacial till on 5 to 40 percent slopes; both have severe erosion hazard (NRCS, 2018).

Near the summit of Vail Pass, the surface material falls within the Scout-Leadville families of soils which exhibits moderate erosion hazard. When the segment of I-70 was built crossing Vail Pass, it was one of the first projects to incorporate erosion control measures. and aesthetics into the design. The reclamation has proven to be effective and mimics the natural landscape. The only minor exceptions are a few steep rock cuts on the north side of the road in the Minturn and Maroon formation that were left exposed without mitigation leaving an erosional surface.

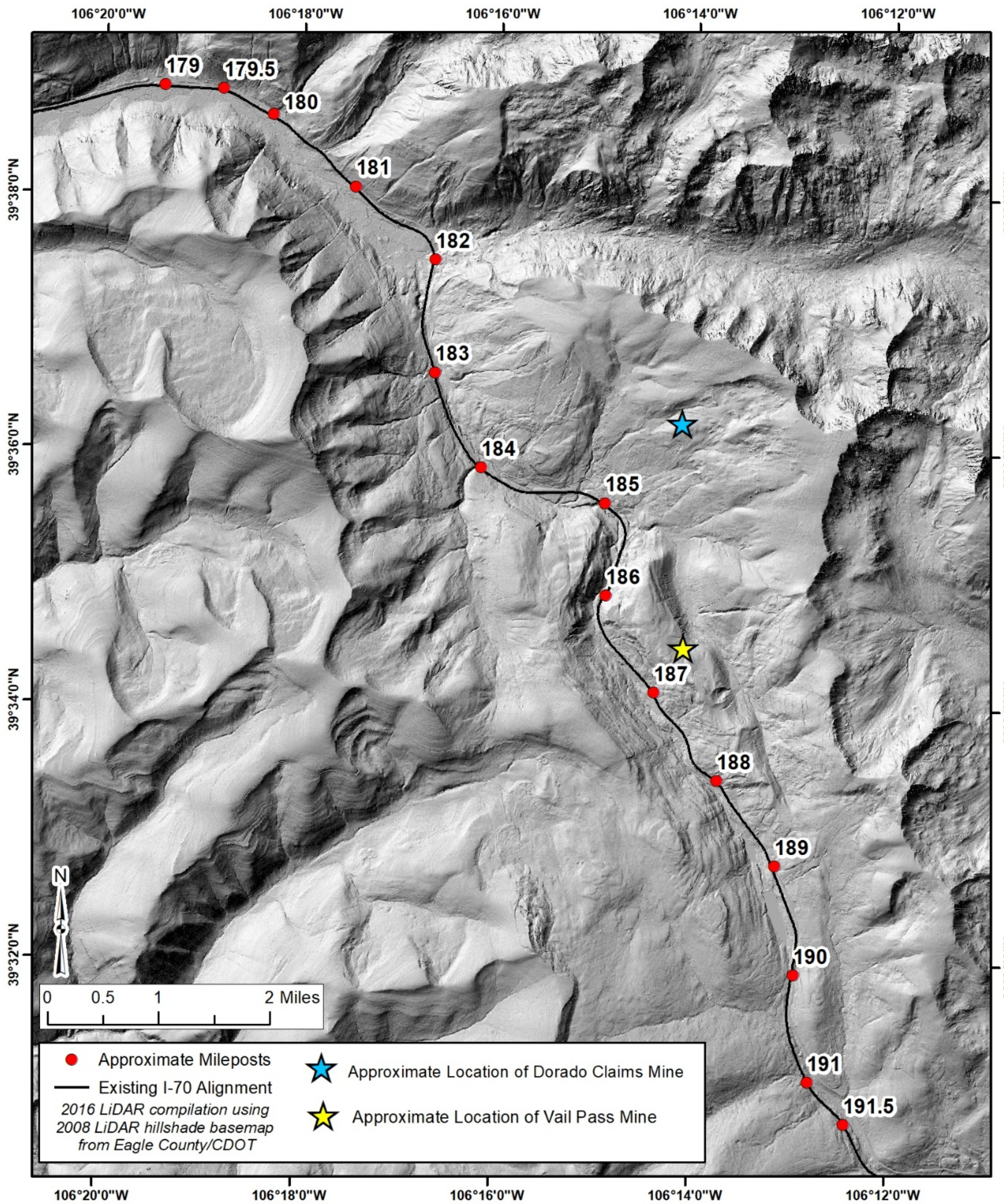
Collapsible soils are associated with rapidly deposited debris and soil material and may occur in the project area in landslide, debris flow, and alluvial fan areas (CGS Collapsible Soil).

North of the interstate in the area of MPs 183.2 to 184.0, a saturated lake deposit consisting of silt and fine-grained sand was encountered during the pre-construction, initial site investigation. The deposit is perched on the hillside and continues to experience intermittent movement. Excavation of poor soils, drainage systems and a wall were used for mitigation.

Mining Activity, I-70 West Vail Pass

Near MP 185, northeast of the interstate, the Dorado group of claims were filed on a uranium deposit in the Minturn Formation during the 1950's. Additionally, near MP 186.5 the Vail Pass Mine was established on an extension of the same deposit in 1956. The claims cover a uranium deposit that is on the hillside north of the highway (Hughes, 2003). Approximate locations are shown in **Figure 4**.

Figure 4. Approximate Location of the Dorado Claims Mine and the Vail Pass Mine Established in Uranium Deposits



Impacts

No Action Alternative

All alternatives, including the No Action Alternative, interact with geologic hazards within the project limits. Under the No Action Alternative, existing problems with slope erosion and geological hazards would continue. Existing hazards such as rockfall, debris flow/mudslides, snow avalanches and landslides may impact the existing facilities. These impacts require ongoing highway maintenance and have the potential to cause roadway closures. New development along the corridor would continue to take place, thus resulting in more geologic risk from existing steep slopes, erosion, and geologic hazards.

Proposed Action Alternative

The proposed widening of I-70 including the auxiliary lanes for both EB and WB, shoulders, emergency turnarounds, and chain stations could potentially increase the exposure to landslides, rockfall, avalanches, and debris flows. The risk associated with the Proposed Action can be reduced with the implementation of landslide, rockfall, avalanche, and possible associated debris flow mitigation in the final design and using best management practices during construction to control slope failures.

Indirect impacts from geologic hazards results from operations and maintenance activities that are required for all alternatives. Activities include periodic maintenance of rockfall and landslide mitigation and cleanup of landslides, rockfall, debris flows and avalanches.

The proposed realignment of the recreational trail/bike path from MP 185 to MP 187 would increase the exposure of the trail facility to avalanches, landslides and rockfall. The design and final configuration of the recreational trail would incorporate mitigation measures to minimize the exposure to the existing geologic hazards. During the winter months the trail/bike path is closed to the public and not maintained and the impacts from avalanches is considered low to public traffic.

Construction activity can impact landslide movement where unstable slopes occur, causing reactivation of existing landslide masses. Additionally, construction activities may increase rockfall hazards where new slopes intersect either weak rock, or loose to marginally stable slopes. These impacts should be limited to the period during construction if managed properly. The design and final configuration of the Proposed Action would incorporate mitigation measures to minimize the impacts from the existing geologic hazards.

The Proposed Action has the potential to increase erosion during construction, especially in the areas where loose soil conditions exist. Erosion also could occur in areas of steep grades where surface water is directed to vulnerable areas, where fill embankments are constructed near loose soil, and where construction occurs along Black Gore Creek and Gore Creek. Areas most susceptible to erosion are located along the I-70 embankment adjacent to Black Gore Creek and the steep cut slopes in the Narrows area from MP 185.5 to MP 186.3.

Mitigation Measures and Best Management Strategies

Relevant mitigation measures identified to address the effects related to the geologic resources are included in **Table 2**.

Table 2. Resource Mitigation Measures

Context		
The study area consists of sedimentary bedrock, mapped as Minturn Formation and Maroon Formation, which can be a few feet to 1,000 feet thick. Glacial deposits range from a few feet to over 90 feet thick in the study area. Alluvial deposits occur in the valley floors of the major streams with alluvial fans occurring only where stream flow is intermittent. Deposits of colluvium generally range in particle size from silt to boulders up to 4 feet in diameter. Geologic hazards in the West Vail Pass corridor include, but are not limited to, landslides, rockfall, avalanches, frost heave and associated possible debris flow.		
No Action Impact	**Proposed Action Impact (Temporary and Permanent)**	**Mitigation**
Soil erosion occurs from existing cut slope primarily in the Narrows area MP 185.5 to 186.3	**Permanent Impacts**: Potential permanent impact from additional excavation at the existing cut slopes in the narrows are (MP 185.5 – 186.6) **Temporary Impacts:** Temporary impact during construction of new slopes and new retaining walls can cause erosion and transport sediments through stormwater runoff.	• Manage erosion and surface water away from water sources and ensure control measures are in place to prevent migration of sediment from waste piles, slopes and excavations during construction. • Minimize slope excavation of the undisturbed slopes and follow natural topography and slope angle when new cuts are constructed. • Using excavation and landscaping techniques, such as slope rounding, terracing, and seeding to establish vegetation to minimize soil loss.
Existing landslide features, including debris flows, are relatively inactive due to design considerations in the original I-70 corridor construction. Frost heave has adversely affected the pavement in the Narrows area. Frequent rockfall and avalanche activity occurs in the Narrows area MP 185.5 to 186.3. Existing highway ditch contains much of the fallen material.	**Permanent Impacts:** Existing landslides can be affected during construction and in the final configuration. Removal of material at the base of the slide or changes in the surface and ground water conditions can lead to instability. Additional excavation of the rock slope in the Narrows area can increase rockfall and avalanche activity. Disturbance of debris flow/alluvial fans may expose collapsible soils. Potential to encounter and impede groundwater, which could result in associated frost heave. **Temporary Impacts:** Similar to permanent impacts.	• Avoid destabilizing existing landslides, debris flow/alluvial fans during roadway construction, which includes minimizing cut slopes and selectively locating embankments. • Using rock sculpting, which involves blasting rock by using the existing rock structure to control overbreak and blast damage to create a more natural-looking cut. Aesthetic treatments for rock cuts will be determined during the Aesthetic ITF. • Using proven mitigation techniques as well as scaling and blasting, to address rockfall from cut slope areas. Determination of rockfall mitigation measures will be based on the slope configuration at final design. Aesthetic treatments for rock cuts will be determined during the Aesthetic ITF. • Use avalanche fencing to manage avalanches.

		• Frost heave mitigation includes methods to prevent water from pooling under pavement such as over-excavation down to frost depth of frost susceptible soils and replacement with non-frost susceptible soils or rigid foam insulation, improve surface and subsurface drainage, and reduce infiltration of water (CDOT, 2016).

PERMITS

No permits are anticipated in association with the Geologic Resources.

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