3.7 Geologic Hazards

This section summarizes the initial investigation of impacts on the geologic resources found in the natural and man-made settings in the Corridor area. The highly complex and varied ground conditions include a wide range of active physical and chemical processes with the potential to pose hazards during construction and operation of the transportation system. I-70 is located along a corridor influenced by numerous faults, adverse rock structure, landslides, rockfalls, debris flows, avalanches, and collapsible soil. Many of these naturally occurring hazards have affected previous projects and continue to affect the mobility of the existing transportation system.

The locations of geologic hazards that would directly affect the proposed alternatives are identified on Maps 3.7-1 through 3.7-4, which can be found in the Resource Maps section. Many other geologic hazards are found in the valley walls and floors of the Corridor, but only those with the potential to affect the proposed alternatives are discussed.

Geologic Hazard Issues

- Potential to exacerbate existing geologic hazards and adversely affect safety, service, and mobility due to rockfalls, debris flows, mudflows, avalanches, landslides, and other hazards
- Potential to intersect areas of geologic instability (adverse jointing fracture patterns and/or bedding) and create geologic hazards
- Engineering constraints due to limitations on stability of slope angles
- Soil erosion, erosion control, and reclamation potential

Construction activities can affect soils in the Corridor through clearing and grubbing, removing soil, and steepening slopes. The severity of erosion depends closely on slope treatment techniques used, physical properties of the soil, and slope angle. Severe erosion can result in unstable slopes with tremendous productivity losses and revegetation issues.

3.7.1 Methods

Existing geologic conditions in the Corridor were identified using information from geologic maps, United States Geological Survey (USGS) reports, Colorado Geological Survey publications, topographic maps, and aerial photographs. Ratings for existing geologic hazards were developed to evaluate the severity of disturbance to an area. Criteria included the influence of climate, proximity to I-70, history of occurrence, and impact on transportation and mobility. Based on these criteria, five categories for geologic hazard severity were developed and are defined below: Severe, High, Moderate, Low, and Slight. The severity rating was then determined for each study section along the Corridor as shown in Table 3.7-1.

A hazard should meet most but not necessarily all of the criteria listed, and each criterion is weighted differently.

- SEVERE (“A”)
  - Impact of the hazard on the alternative is so great that any disturbance of the hazard for improvements is not recommended.
  - Hazard is generally directly adjacent to the alternative or will directly impact alternative.
  - If failure,
    - There is long-term loss of service to alternative, area is not traversable, or traveling public must stop.
- HIGH (“B”)
  - Impact of the hazard on the alternative is great.
  - Hazard is generally less than 50 feet from the alternative or will directly impact alternative.
  - There is visual evidence of very recent activity (1 to 3 years) [*frequent recurrence interval*].
  - If failure,
    - There is long-term loss of service to alternative, area is not traversable, or traveling public must stop.
    - Immediate mitigation is required.
  - No mitigation has been previously implemented.
- MODERATE (“C”)
  - Impact of the hazard on the alternative is moderate.
  - Hazard is generally less than 500 feet from the alternative.
  - There is visual evidence of recent activity (3 to 10 years).
  - If failure,
    - There is moderate loss of service to the alternative, impedance to less than half of the template, or traveling public must avoid obstruction.
    - Long-term mitigation is needed.
    - Periodic maintenance is required.
  - Some limited or partially effective mitigation may have been implemented in the past
- LOW (“D”)
  - Impact of the hazard on the alternative is minimal.
  - Hazard is generally more than 500 feet from the alternative.
  - There is no visual evidence of recent activity (more than 10 years).
  - If failure,
    - There is little or no loss of service to the alternative, impedance of shoulder or less, or no noticeable damage.
    - No mitigation is necessary.
    - One-time maintenance is needed.
  - Includes areas where extensive, but mostly effective mitigation has been done.
- SLIGHT (“E”)
  - Natural hazard does not pose a problem to the alternative.
  - If failure,
    - There is no loss of service to the alternative.
    - No mitigation is necessary.
    - No maintenance is needed.
  - Includes areas where extensive, but highly effective mitigation has been done.
  - Includes all unmodified “Undifferentiated Hazards” from USGS 1^{o} x 2^{o} map.
  - Includes areas that are blocked from the highway by a physical barrier (ridgeline, valley, negative difference in elevation, stream). In this case, the hazard can be within 500 feet of alternative.

Supporting Documentation

- Appendix A, Environmental Analysis and Data
- Resource Map 3.7-1 through 3.7-4, Corridor Geologic Hazards

Soil erosion potential was based on maps and reports from Natural Resource Conservation Service (NRCS) and the US Forest Service (USFS). The NRCS provided K and T factors, erodibility groups, and soil descriptions. The soil loss tolerance (T) value represents the average annual rate of soil erosion that could occur without causing a decline in long-term productivity, and K is the soil erodibility factor. The USFS provided erodibility descriptions and management considerations. Soil ratings by the NRCS and the USFS are slight, moderate, or severely susceptible to erosion.

3.7.2 Affected Environment

3.7.2.1 Geologic Setting

A wide range of geologic conditions exists and is exposed throughout the Corridor, with a vast amount of time represented in the multiple rock formations. The geologic time represented in the Corridor ranges from recent river, debris, and mudflow deposits to Precambrian rocks between 1 and 2 billion years old. Most of the rugged terrain associated with the Rocky Mountains was formed approximately 72 million years ago during a period that lasted about 7 million years. Numerous faults and folds along the Corridor depict the extensive tectonic episodes.

The Corridor's multiple sedimentary units resulted from erosion of a mountain range that predates the present Rocky Mountains, and numerous advances and retreats of inland seas. The resulting formations include shale deposits representing shallow sea environments; sandstone and quartzite deposits representing beach environments; and limestone deposits representing offshore coral reefs.

The present topography represents 20,000 years of erosion. With the notable exception of widespread glaciers, the processes that impose hazards on current activities have been active during these years. Most of the present configuration of valleys, mountains, and canyons seen along the Corridor resulted either directly or indirectly from alpine glaciation. Cirques and U-shaped valleys are features associated with glaciation.

After the periods of glaciation, most of today's valleys were cut by streams and rivers to form the classic V-shape. Rain, snowmelt, and wind created deposits of talus and alluvial fans.

3.7.2.2 Soils

A wide variety of soils are found in the Corridor. Source materials for soils in the Corridor vary from gneiss, granite, volcanics, sandstone, and shales to colluvium, alluvium, and glacial deposits. Slope angles range from nearly horizontal along valley floors to vertical along valley sides. Soil and productivity loss are related to the degree of slope, reclamation effort, footprint of impact and climate. Challenges to revegetation are limited water availability, low water retention, low inherent fertility, and steep slopes.

Engineering constraints related to soils are closely tied to engineering geology and geologic hazards. For example, exceeding thresholds for slope stability will cause slope failure without proper mitigation. These issues are addressed in section 3.7.2.4.

3.7.2.3 Overview of Geologic Hazards

A geologic hazard is a geologic process that creates risk or potential danger for human life or property (Rahn 1996). The varied and complex geology and geomorphic processes found in the Corridor have created several zones of instability with marginal subsurface material. Some of these features pose risks to humans either directly by encounter or indirectly by effect on roadways, railways, and/or buildings. Conditions that may adversely affect both humans and/or proposed improvements in the Corridor include faults, poor rock structure and/or quality, and existing geologic hazards (debris flow, mudflow, rockfall, landslides, avalanches, collapsible soil, and rapid subsidence).

Geologic structure, slope configuration, precipitation, wind, and extreme temperature fluctuations all contribute to geologic hazards along the Corridor. The climate includes wetting and drying, precipitation, freeze-thaw, and snowmelt. Little vegetation cover on most slopes makes them highly susceptible to erosion.

Landslide

Landslides include movement of both competent material (rockfall) and incompetent material (debris flow). Debris flow and rockfall are subcategories of landslides but involve different modes of failure. Landslides are distinguished from debris flows by the method and means of material transport downslope. Unlike flows, slides occur along a defined slip surface and usually have a defined scarp at the head that forms a steplike appearance.

South-facing slopes are usually characterized by lack of vegetation and thin, dry soil. These conditions are prone to small-scale debris flows and rockfalls. Landslides and large-scale debris flows are more common on north-facing slopes characterized by dense vegetation cover, a thick soil mantle, and higher soil moisture. Although slope failures occur less often on north-facing slopes than on south-facing slopes, north-facing slides are much greater in magnitude.

Debris Flow and Mudflow

Debris flows and mudflows are formed by a rapid downslope plastic flow of debris. They occur where soils are poorly anchored and during violent storms when runoff is produced faster than the ground can absorb it. Stormwater runoff carries a viscous mixture of water, soil, rock, and sometimes vegetation. This material is deposited in fan-shaped formations in valleys and at the toes of slopes.

Rockfall

Many conditions can affect a slope and lead to rockfall; usually more than one factor contributes. Geological factors such as rock type, structure, and discontinuity characteristics must exist for rockfall to occur. Different types of rockfall occur in different geologic situations. The conditions that cause rockfall generally fit into one of two categories. In one case, joints, bedding planes, or other discontinuities are the dominant structural feature of a rock slope. In the other case, differential erosion or oversteepened slopes are the chief cause of rockfall (Andrew 1994). Rockfall of this second type is of particular concern in the area between Silver Plume and Georgetown, commonly referred to as the Georgetown Incline, where rocks from an unstable slope have fallen onto I-70, causing injuries and fatalities.

Avalanche

An avalanche is a large mass of snow or ice that moves rapidly down a slope. Avalanche chutes appear as elongated, narrow, barren scars on a mountainside. Often a fan-shaped deposit is found at the base of an avalanche chute. Some avalanches form during periods of high wind that cause rapid accumulation of snow on cliff faces. These break off in large sheets.

The Colorado Department of Transportation (CDOT), in collaboration with the Colorado Avalanche Information Center (CAIC) forecasters, monitors avalanche hazards and conducts mitigation as necessary to keep the avalanche hazard along Colorado highway corridors to a minimum. Existing avalanche paths are monitored by CAIC forecasters, and avalanche mitigation is conducted with explosive charges designed for avalanche control. However, extraordinary circumstances, such as the heavy snow season of 2002–2003, can cause unusual, unpredictable avalanche activity. An avalanche that affected I-70 in the Silver Plume area in 2003 is discussed in the Silverthorne to Silver Plume (mileposts 203 to 227) section.

3.7.2.4 Corridor Constraints and Hazards

For discussion purposes, 10 geologic domains in the Corridor were identified by their geologic features and defining geologic conditions. The discussion for each domain includes the general geology that is the cause or contributor to the geologic hazards and engineering constraints that could affect the transportation alternatives.

Glenwood Canyon (Mileposts 119 to 133)

The White River Plateau is located partly in Garfield County and partly in Eagle County. No physical changes are proposed for this area; therefore, general geology of the domain is not analyzed here.

The most prevalent geologic hazard in Glenwood Canyon is rockfall. Although some risk still exists, mitigation measures have reduced the incidence of rockfall. Soils between mileposts 130 and 134 have the potential to subside or settle rapidly. The subsurface material susceptible to this phenomenon is the result of geologic lake deposition of soft clay.

Eagle Valley to Wolcott (Mileposts 133 to 157)

The Eagle Valley cuts through bedrock of highly erodible, sparsely vegetated sedimentary rocks bounded on both sides by Eagle Valley Evaporites. The Eagle Valley Evaporites are composed mainly of halite, gypsum, and anhydrite, with some potassium salt deposits. Evaporative rock is prone to risks from collapsible soils and debris flows. Collapsible soils are found near Eagle (milepost 147) and Gypsum (milepost 140) as shown on Map 3.7-1, which is located within the Resource Maps section (Robinson 1975). Subsidence is very generalized and not usually accompanied by differential movement that would affect structures. I-70 was built in the deposit zone of a series of debris flows, but construction did not affect the source areas.

The Wolcott landslide complex shown on Map 3.7-2 (see Resource Maps section) is located on the south side of the highway at the east of this domain (milepost 154 to 159) (Colton 1975). Overburden and blocks of sedimentary rock moving in a metastable state characterize this complex landslide.

During construction of I-70, large blocks of bedrock slid and arrested in a metastable state on the west side of the Wolcott exit. The road was realigned because no reasonable mitigation was possible. Recently one lobe east of the exit was mitigated with tieback anchors. Here, the overburden was sliding on the bedrock surface dipping into the roadway, necessitating costly pavement repairs to I-70 and US 6. Because of this impact on I-70 alignment, and the potential for future movement, this slide is classified in the Severe category.

Wolcott to Dowd Canyon (Mileposts 157 to 171)

Red sandstones of the Pennsylvanian-Permian period(s) characterize much of this domain. The rock is fractured with interbedded shale and sandstone layers. The more massive sandstone layers create many of the cliff-forming slopes (Lidke 1998). Due to the complex folding that occurred here, the bedding dips into the highway in some places, creating potentially unstable slopes. The dip of the bedding contributes to landslide and rockfall hazards, especially near Dowd Canyon (Map 3.7-2, located in the Resource Maps section).

The Whiskey Creek landslides (see Figure 3.7-1) on the south side of the highway between mileposts 169 and 171 are a complex group of old landslides where alluvium, colluvium, and glacial deposits overlay sedimentary rocks on dipping surfaces. Construction of I-70 mobilized several lobes of these landslides beginning in the late 1960s, continuing to their present configuration.

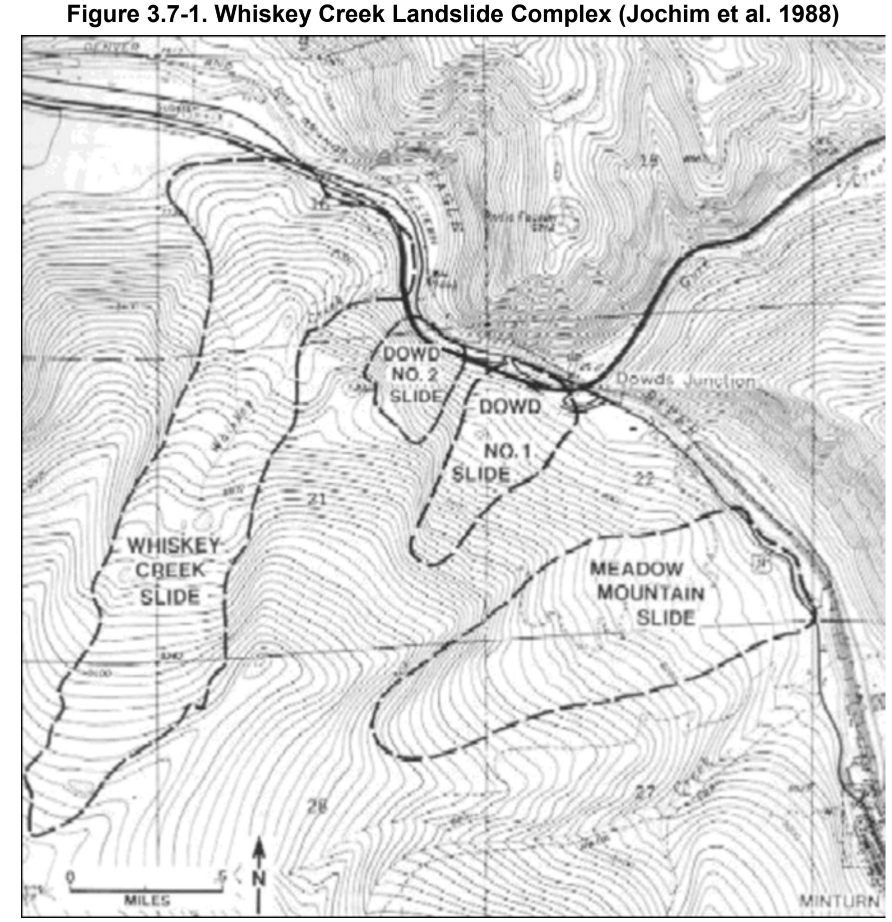
A series of slope movements took place in the mid-1980s after a couple of winters of heavy snowfall. In the spring of 1984, the Dowd No. 1 movement forced closure of eastbound I-70 and the US 24 interchange. In 1985, the Meadow Mountain slide and Dowd No. 1 mobilized, causing partial loss of US 24 and damage to the bridge at the I-70/US 24 interchange. The state of Colorado declared a landslide alert immediately afterward, and the governor established the Minturn Earthflows Task Force. The task force was charged with analyzing the geology of Dowd Canyon and developing recommendations for federal, state, and local governments on how to mitigate the effects of any catastrophic slides in the area.

Geologic investigations and monitoring programs were conducted at the time of the task force analysis. The task force identified more than 40 options ranging from "do nothing" to "stop it from moving." Each option addressed the implications of the slide complex mobilizing and damming the Eagle River and the potential loss of a significant transportation corridor (Jochim et al. 1988).

After a review of the studies conducted for the Whiskey Creek landslide complex and the measures recommended by the task force, it has been determined that more information about the behavior and characteristics of the slides is required. The landslide complex with a severity index of A was placed on the state's landslide priority list.

Construction of I-70 encountered continual slope failures in this area, with parts of the construction shut down for extended periods of time. Existing retaining structures and bridges show signs of damage and continued movement due to the slides in the area.

Figure 3.7-1. Whiskey Creek Landslide Complex (Jochim et al. 1988)



Dowd Canyon to Wheeler Junction (Mileposts 171 to 195)

The Gore Fault bounds the west side of the Gore Mountain Range and sets older metamorphic and granite rock against the younger Pennsylvanian-Permian sedimentary red beds. A series of rock excavations through Dowd Canyon between mileposts 171 and 173 exposed weaker bedrock units, resulting in rockfall originating from the cut slopes. The sedimentary units are composed primarily of interbedded sandstone and shale with joint sets that run perpendicular to the bedding planes. This adverse structure and the differential erosion between the units, coupled with the designed cut slope, created the unstable slope condition. Catchment areas were provided at the base of the cut slopes, but rock and debris have reached the highway due to the volume of material in many of the failures. Some failures have been massive, forcing closure of I-70. These rockfall hazards have been identified with a severity index of B as shown on Map 3.7-2, located in the Resource Maps section.

The Minturn Formation in the Dowd Canyon area is composed of sandstone units more massive than the Pennsylvanian-Permian sandstone formations along Vail Pass. Shallow groundwater and high water pressures can potentially create difficulties during construction.

The Vail Valley and the east side of Vail Pass display U-shaped slope walls characteristic of alpine glaciation. During construction of Vail Pass, numerous preexisting landslides were mobilized when cuts into the hillside were made (Barrett and Cochran 1975). Slides occurred in overburden, alluvium, colluvium, glacial deposits, and dipping beds of sedimentary rock. Extensive erosion control measures and aesthetics were incorporated into the highway design. The configuration of the rock excavation is ideal for accumulating snow at milepost 187. Slab avalanches and rockfall develop at this location, carrying dense snow, rock, and other debris (Map 3.7-3, located in the Resource Maps section).

Any construction in this area will require mitigation of existing slope instability. In previous Vail Pass I-70 projects, horizontal drains and buttresses were used extensively and have been performing to date. Tiebacks and other positive reinforcement methods also may be required, depending on the amount of excavation and other slope geometry requirements (Robinson and Cochran 1983).

Rock sculpting techniques were used at several locations along Vail Pass. These excavations provided more natural-looking rock slopes. Due to the bedding planes and existing discontinuities in the bedrock units, this method of excavation provided a stable cut slope configuration.

The soils on valley and mountain sides from Dowd Canyon to West Vail are moderately to severely susceptible to water erosion. Soils from Vail Pass (milepost 183) to Wheeler Junction (milepost 195) present a moderate erosion hazard. This segment of I-70 was one of the first projects to incorporate serious erosion control measures and aesthetics into its design. Overall, reclamation has proven to be effective and mimics the natural landscape. However, a few steep rock cuts on the north side of the road in the Permian Maroon Formation were left exposed without mitigation, creating an erosional surface.

Wheeler Junction to Silverthorne (Mileposts 195 to 203)

Tenmile Canyon was formed by glaciers and stream erosion that occurred along a zone of weakness (a fault line). Area bedrock is very resistive and is composed primarily of granite and metasedimentary gneisses. Extensive glacial deposits, colluvium, and stream deposits make up most of the surface deposits. Extensive glacial deposits are present along the slopes north of Frisco. These deposits have been deeply incised by runoff from the Gore Mountain Range (Bergendahl 1963). The subsurface material in the area between Frisco and Silverthorne area is composed of Pierre shale. Poorly designed excavations in the shale unit have caused shallow landslides along the north side of Silverthorne (Bergendahl 1969).

Several small avalanche chutes are located along the south side of Tenmile Canyon between mileposts 195 and 200. Although these chutes rarely reach the valley floor during average winter snowfall, one avalanche did reach the creek during the winter of 2000. Rockfall hazards originated from rock excavations during original I-70 construction. Most of the localized failures from these cuts were caused by overbreak or fractures in the rock caused by blasting.

Silverthorne to Silver Plume (Mileposts 203 to 227)

This domain is located partly in Summit County and partly in Clear Creek County. This domain includes the Continental Divide, with Straight Creek on the west side of the Eisenhower-Johnson Memorial Tunnels (EJMT) and Clear Creek on the east side of EJMT.

Straight Creek

Metamorphic and igneous rock along both flanks of the Continental Divide characterize most of this domain. Rock quality ranges from poor to good and is characterized by adverse structure that contributes to landslides along Straight Creek between mileposts 214 and 217. Several substantial faults intersect the area. A number of geologic hazards along Straight Creek are associated with the poor rock quality and a fault that parallels Straight Creek.

During the construction of the cut slopes for I-70, six older landslides on the west side of the Continental Divide were exposed and reactivated. The slides are identified as severity A slides on Map 3.7-3 (see Resource Maps section). These landslides were remnants from earlier slope failures and were located on steep bedrock of poor rock quality and adverse structure. Construction removed the toe of the slides above the roadway, causing the slides to move into the roadway. Drainage, realignment, and reduced slopes were used to mitigate the slides. The original I-70 highway grade is buried under the slide; the road passes around it at milepost 211.5 (Noble 1969).

Soils in the cut slopes of the western approach to the EJMT consist of glacial deposits and igneous and metamorphic rock that are highly sensitive to erosion at their current slope angle. The exposed bedrock has adverse structural characteristics that have been responsible for large slope failures and slides during construction. Steep slopes in both rock and soil have hindered attempts at revegetation. The short growing season and avalanches also make revegetation difficult.

Eisenhower-Johnson Memorial Tunnels

Geological information available in the 1960s and 1970s during construction of the Straight Creek Tunnel (now the Eisenhower-Johnson Memorial Tunnels) indicates that the geology is generally complex. The eastern and western sides of the Continental Divide differ greatly from each other directly along the tunnel alignment. The primary rock type on the western side is likely hard granite, relatively intact with minimal fracturing and/or faulting.

Rock types on the eastern side likely consist of granites and granite/migmatite mixtures. The intact strength of these rock types is typically high unless faulting or fracturing is present, which greatly diminishes rock strength. Large-scale fault and shear zones appear to be relatively common on the eastern side of the Continental Divide. The major fault system in the vicinity of the Continental Divide is the Loveland Shear Zone. This shear zone consists of numerous faults and smaller shear zones of diverse orientation that generally trends northeast to southwest. The shear zone appears to encompass the ground from the top of the Continental Divide to east of the current I-70 eastern tunnel portals. In many places along the zone, fault movement has sheared the bedrock into a fault gouge having the consistency of sandy clay. Tunneling operations/excavation through the fault gouge encountered "squeezing" and/or "running" ground conditions. Squeezing ground is generally considered an area where the ground stress around the tunnel opening exceeds the strength of the intact or in-situ rock. In this case, the ground will tend to deform plastically and squeeze into the tunnel opening. Due to the amount of overburden above the tunnel, the pressures encountered can be considerable and, consequently, extensive delays occurred during the EJMT construction. Successful excavation through the squeezing ground (fault gouge) involved the use of multiple drift tunneling methods through the fault gouge in a perimeter around the final tunnel excavation.

High groundwater flow was also encountered during the original EJMT construction. Groundwater movement within the rock mass is generally controlled by fracture flow. In areas where rock is intact, groundwater flow is typically absent. Conversely, groundwater flow is greater in areas where bedrock is highly fractured. The USGS evaluated the bedrock influence on water quality in the area of the EJMT during the drilling of the pilot bore. Test results indicate that mineralized zones such as those mined in the Georgetown-Silver Plume district do not occur in tunnel rock. Measured pH levels in the groundwater ranged from 7 to 8.4, demonstrating that acid drainage does not exist.

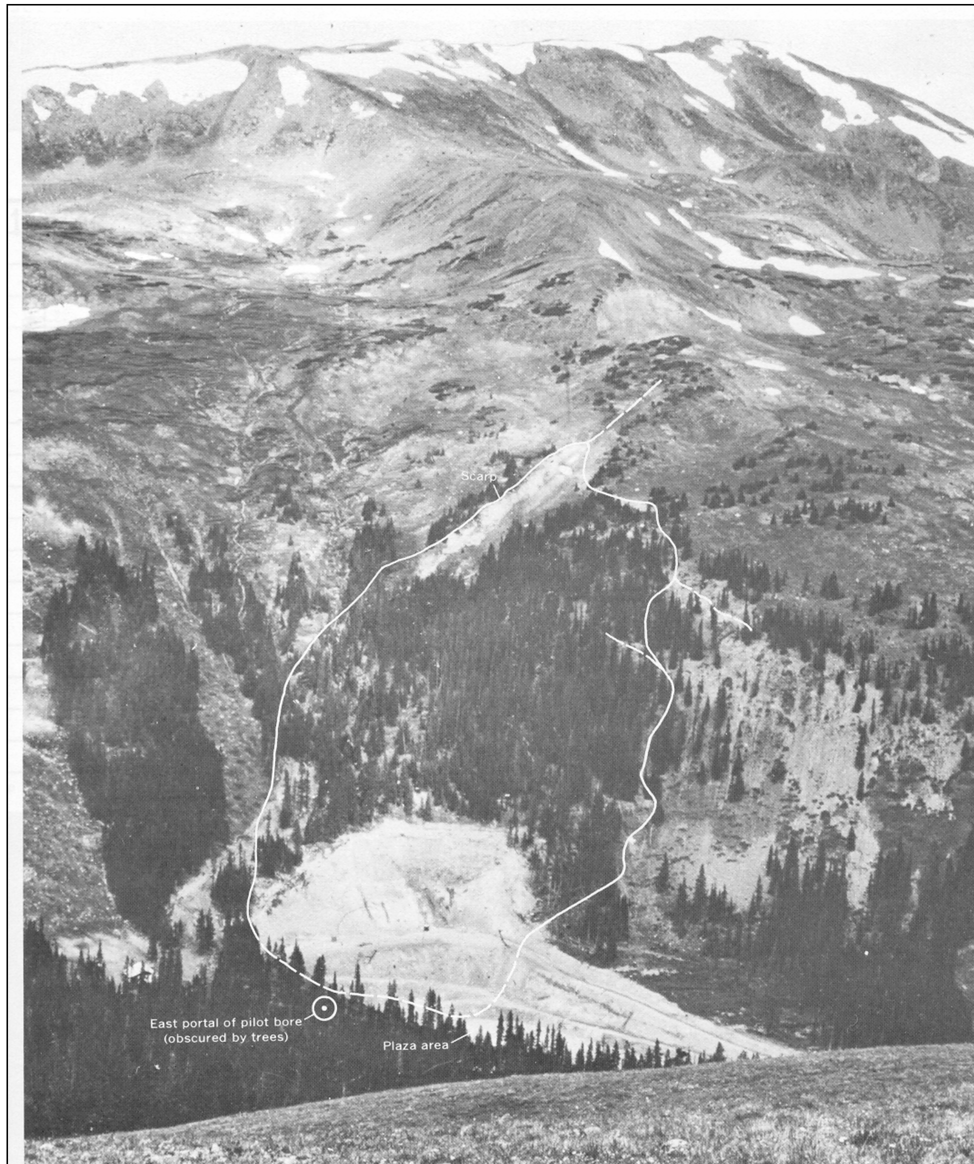
Other regional faulting appears to occur to the east, in the form of splays related to the Loveland Fault. The splays create a regional shear zone likely between 2,000 and 3,000 feet across. Within the regional shear zones, sections of hard, intact rock can be intermixed within faulted sections (Robinson et al. 1974).

Excavation of the EJMT east portal triggered a landslide of approximately 6 million cubic yards, known as the East Portal landslide. Figure 3.7-2 illustrates the landslide area in 1965. The slide self-arrested in a metastable state on a complex slip plane of highly fractured rock. It was then stabilized with a berm approximately one-fifth the slide mass of the toe (Robinson et al. 1972). As much as 14 feet of displacement was reported at the apex of the slide after the event. The fact that this was an area of historic mass movement and that the slope was in a metastable state was apparently not recognized until after the slope failure.

Inclinometers, piezometers, and survey points were installed in the Loveland Basin slide to monitor the movement and effectiveness of the mitigation efforts. Analysis at the time suggested that mitigation efforts were successful. Because the monitoring program was stopped shortly after completion of the tunnels, it is difficult to determine whether the slide has been completely mitigated.

Runout zones of several avalanches are located along the western approach to EJMT. The chutes on the mountainside above the west portals (as shown on Figure 3.7-3) are more active, and could potentially reach the interstate. (I-70 has been closed in the past due to avalanche hazard here.) Avalanches originating from the southern flank of Mount Bethel east of EJMT have been mitigated by installing a snowdrift fence and constructing a detention basin in the runout zone. Charges dispensed from helicopters are used to activate snowslides that could potentially threaten I-70 and appear to be an effective means of mitigating such hazards.

Figure 3.7-2. East Portal Landslide, 1965



FRONTISPIECE.—Loveland Basin landslide, view northwestward (1965).

Figure 3.7-3. Avalanche Chutes, EJMT West Approach

Figure 3.7-4. Cut-and-Fill Slopes Along I-70

Clear Creek

Generalized soils from Bakerville to Silver Plume are derived from granite and found on 30 to 80 percent slopes. These soils are severely susceptible to erosion. Large debris flows have developed in Watrous Gulch (milepost 219.8) and at the former town site of Brownville (milepost 224.8; buried in a debris flow in 1912). The most recent debris flow from Watrous Gulch occurred in July 1999. The flow deposited an estimated 3,520,000 cubic feet of debris up to about 23 feet deep, including boulders up to 7 feet in diameter, on and near I-70, closing the interstate for about 24 hours.

During construction of the Silver Plume interchange (milepost 226), extremely soft silty clay deposits were encountered. The bridge and abutments began to settle immediately after construction ended. Repairs to the structure were required due to the damage caused by the settlement.

In March 2003, a very large avalanche released on the north slope of Pendleton Mountain just west of Silver Plume. The release considerably expanded and extended the avalanche path down to Clear Creek and I-70. Evidence of past avalanche activity showed that avalanches had stopped on a bench at midslope (10,300 feet). However, this avalanche broke through and grew in size as it tumbled down the mountain, carrying the entire season's snow cover along with trees, rocks, and boulders. The avalanche slammed onto the frontage road and choked Clear Creek with snow and trees. Five hundred feet of the frontage road was buried up to 20 feet deep. Minor amounts of debris spilled in the eastbound lanes of I-70, and tree branches were blown across the westbound lanes. The avalanche was extraordinary in its size and length; weather, terrain, and snowpack conditions had combined to produce an unusual avalanche (CAIC 2003).

In Figure 3.7-4, cut-and-fill sections are obvious from the poorly vegetated slopes left after construction of I-70. Recently, this area has been part of an aggressive revegetation and erosion control program implemented by CDOT to mitigate many of the effects of previous I-70 construction.

Silver Plume to Dumont (Mileposts 227 to 234)

The structure of the rock units in this area was influenced by deformations during the Precambrian and the Laramide orogeny in the Tertiary Period. The Silver Plume Formation rock units (Precambrian 1.4 billion-year age group) are less fractured and more resistant to weathering, and form steeper and more massive sidewalls. The Idaho Springs Formation (Precambrian, more than 1.7 billion years old) is characterized by relatively poorer rock quality and more pervasive rock structure.

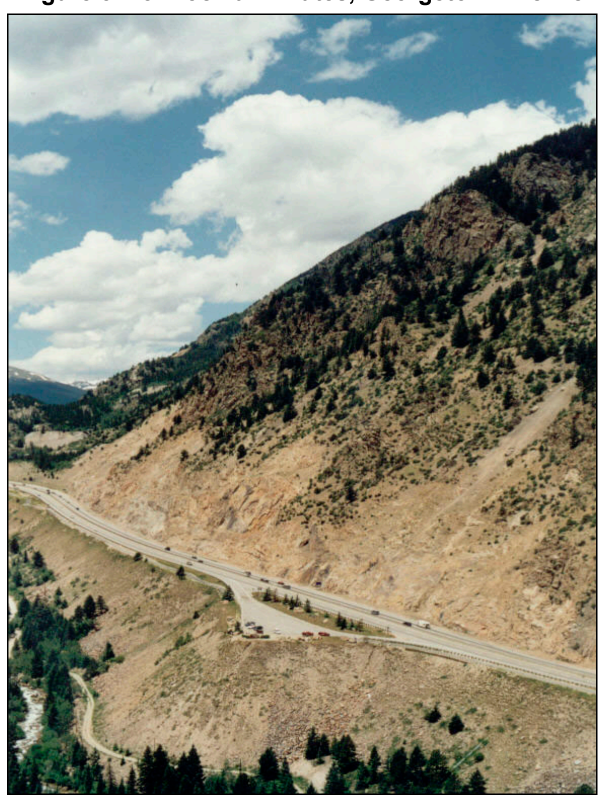
The present topography and surficial deposits in the area have been influenced by stream and glacial erosion and deposition. Overburden soils consist of soil mixed with country rock developed through weathering and freeze-thaw cycles on the bedrock. Oversteepened slopes resulted from glacial activity in the area and were exposed when the glaciers retreated. Unstable colluvium and rocks from debris flows are exposed near the surface of the steep slopes. Debris flows continue to occur during certain climatic conditions. Glaciation effects terminate near the I-70/US 40 junction at milepost 232. From this point downward the valley has a more classic V-shape indicative of stream erosion.

Georgetown Hill climbs up the narrow valley near Georgetown between mileposts 225.5 and 227.9, and is the steepest segment of I-70. The highway was built through a number of rockfall, debris flow, and avalanche deposition zones. I-70 construction cut into the colluvium slopes and bedrock leaving vertical rock cuts and oversteepened colluvium slopes. Although many of the unstable colluvium slopes were excavated, some lie directly above the rock cuts and contribute to rockfall. During construction of the existing I-70 alignment, some of these deposits were used to build the highway embankment. Oversteepened colluvium slopes can become unstable, resulting in shallow slope failures (Hecox 1977). Also, some sections of the rock cuts contain loose and highly fractured material.

The steep cut-and-fill sections were left with minimal mitigation after highway construction. (Often slopes were left as steep as the material could hold. This was accepted practice at the time and is seen throughout the Corridor.) Rockfall is apparent throughout the Georgetown Incline and Clear Creek Valley (Map 3.7-4, located in the Resource Maps section). The recorded history of rockfall events includes accidents on the roadway with injuries and fatalities. Approximately 100 accidents due to rockfall have occurred here in the past 24 years, resulting in many injuries and several fatalities. Seven fatalities due to rockfall have occurred on I-70 near Georgetown since 1995, two of them in August and September of 2003 (*Rocky Mountain News* 2003). Major unreported rockfall activity and events have occurred as well, as evidenced by the full ditches along westbound I-70 and boulders and cobbles covering the embankments of eastbound I-70. Figure 3.7-5 depicts numerous rockfall chutes along the Georgetown Incline.

Rockfall mitigation measures are installed at selected locations along the Georgetown Incline to mitigate rockfall originating from the area disturbed by previous I-70 construction. Due to the size and severity of many events originating from the vast natural slopes, these mitigation measures are not completely effective. Scaling of the natural slopes has been ruled out because of potential effects on the town of Georgetown and the Georgetown Loop Railroad, as well as the potential to accelerate erosion by disturbing vegetation.

Figure 3.7-5. Rockfall Chutes, Georgetown Incline



Debris flows occur in this area north of Georgetown Lake, along the lower portion of the east-facing flank of Columbia and Democrat Mountains. Multiple events have occurred in the last 20 years on a hillslope directly above the highway. In July 1999, debris flows occurred in about 20 channels on this hillslope. The volume of debris from these flows was relatively small (generally less than 131 cubic yards); about five flows affected I-70. Other debris flow and rockfall events that affected the town of Georgetown have been documented.

Dumont to Idaho Springs (Mileposts 234 to 241)

Mineralized metamorphic rock from the Idaho Springs Formation characterizes this area. The terrain is rugged with steep V-shaped canyons. Rock quality ranges from good to poor, and structure may or may not be adverse, depending on valley side. Steep slopes on the north side and Clear Creek on the south side confine the highway platform. Rockfall is the most prevalent geologic hazard in this domain. The original designs of I-70 and US 6 are the cause of many of the rock slope stability problems here.

Rock excavations on the north side of the valley would cause fewer problems than along the south side due to the bedrock structure. Because the rock structure trends to the north-northeast, any excavations along the south side of the valley could trigger slope failure without proper design. Natural landslides in this area were apparently caused by Clear Creek cutting and undermining the canyon walls.

Rock excavations during original construction of US 40 (and later I-70) exposed areas of mineralized rock. This feature is most evident between Fall River Road at milepost 237 and Idaho Springs near milepost 239, in the colorization of the outcrops. Areas of mineralized rock are discussed further in section 3.8, Regulated Materials and Historic Mining.

Idaho Springs to Hogback (Mileposts 241 to 259)

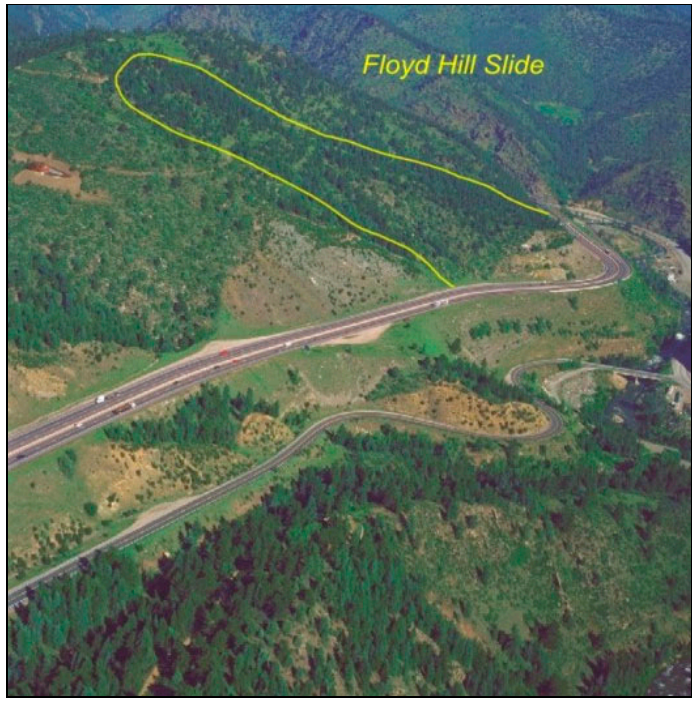
The eastern entrance to the Corridor from Floyd Hill to Lookout Mountain is characterized by metamorphic rock with varying degrees of metamorphism and includes amphiboles, schist, and gneiss. The terrain is steep with V-shaped canyons. Geologic exposures are dramatic, and the steep cut through the friable (crumbly or easily broken) rock has deposited a continuous rain of boulders and gravel at the base of the slopes. Lack of soil, organic matter, nutrients, and water, combined with the oversteepened slope, has left exposed bare rock with little or no productivity and susceptibility to erosion.

The Floyd Hill rockslide, on the south side of I-70 where US 6 merges with the highway at Clear Creek Canyon (milepost 244.5), consists of highly fractured and foliated rock. The slide is identified as a severe rockslide in Map 3.7-4 (see the Resource Maps section). A series of rock cuts made through this area during construction of US 40 and I-70 removed material at the base of the slope and caused a large rockslide. As shown in Figure 3.7-6, I-70 was realigned to reduce the size of the cut, allowing room for the slide to move and lessening further effects on the highway. The Floyd Hill rockslide remains active; major movements follow extended periods of heavy precipitation.

Tunnel alternatives being considered to smooth curves near the base of Floyd Hill should be carefully evaluated for potential effects on groundwater and, more specifically, existing water wells. Groundwater in this area flows through fractures in metamorphic rock, which is sensitive to blasting and other fracture modifications. In addition, tunnel construction might drain area aquifers and draw down groundwater levels in some areas. Additional information on subsurface conditions is required to assess potential effects on groundwater.

Ground subsidence from past mining has affected the highway at Hidden Valley (milepost 243) and in Idaho Springs. The extent of this hazard is unknown at this time. Subsidence from historic tunneled mine workings remains a hazard in these areas; further investigation is needed to determine the extent of the openings.

Figure 3.7-6. General Boundary of Floyd Hill Rockslide



The terrain on the east side of Floyd Hill consists of rolling hills. Rock is not mineralized and ranges from good to poor quality, with a number of major and minor faults (Reed et al. 1973). Rock excavations along US 40 through Mount Vernon Canyon generate rockfalls that affect US 40 and occasionally I-70. Isolated areas in these road cuts have generated larger, more troublesome rockslides. Some slides have been large enough to close US 40 for extended periods of time.

Hogback to C-470 (Mileposts 259 to 262)

Bedrock changes abruptly just west of the Morrison exit from Precambrian metamorphic rock to the steeply dipping upper Paleozoic sedimentary rocks. The Dakota Hogback is capped by the resistive Dakota Sandstone, and runs along much of the Front Range near Denver. Although the road cut at the Hogback is highly erodible, little rockfall has originated from this cut.

One of the more notable rock units in this domain is the Morrison Formation. In the summer of 1877, the Morrison Formation gained attention when local professor Arthur Lakes discovered dinosaur fossils there. Afterwards, O.C. Marsh from Yale University sponsored excavation of several quarries near the area now known as Dinosaur Ridge, uncovering several unique fossils. Among the discoveries in the Morrison Formation, Marsh found and named several specimens that were the first dinosaurs of their kind ever discovered, as well as the first dinosaurs found in the western US. These included *Stegosaurus armatus, Diplodocus, Allosaurus*, and *Apatosaurus ajax*.

The road cut east of the Morrison exit displays many rock units of the Mesozoic Era. Embankment material for I-70 between the Hogback and C-470 has been more problematic. In the early 1980s, large failures in the fill material developed into a major landslide. Several eastbound lanes of I-70 were closed for 9 months until the slide was stabilized and repaired. Any construction cuts or fills in the embankment area should be carefully designed to avoid disturbing the marginally stable material. Adequate drainage of the improvements will be the most effective means of avoiding future slope failures.

Summary of Geologic Hazards

Table 3.7-1 summarizes the current geologic conditions in the Corridor and provides an index indicating the severity (slight, low, moderate, high, or severe) of the hazard.

Table 3.7-1. Current Geologic Conditions and Severity Index

Geologic Condition	Glenwood Canyon (White River Plateau) (mp 119–133)	Eagle Valley to Wolcott (mp 133–157)	Wolcott to Dowd Canyon (Red Sandstone) (mp 157–171)	Dowd Canyon to Wheeler Junction (Gore Range) (mp 171–195)	Wheeler Junction to Silverthorne (Tenmile Canyon) (mp 195–203)	Silverthorne to Silver Plume (Continental Divide) (mp 203–227)	Silver Plume to Dumont (Glaciated Valley) (mp 227–234)	Dumont to Idaho Springs (Mineralized Zone) (mp 234–241)	Idaho Springs to Hogback (Rolling Hills) (mp 241–259)	Hogback to C-470 (Front Range Hogback) (mp 259–262)
Adverse faulting	Low	Low	Low	Moderate	Moderate	Severe	Moderate	Moderate	High	Moderate
Adverse rock structure	Low	Low	Low	High	Severe	Severe	Moderate	High	High	Moderate
Poor rock quality	Low	High	High	Moderate	Low	Severe	Low	Low	Moderate	Moderate
Debris flow	Low	High	Moderate	High	Moderate	High	High	Low	—	—
Rockfall	High	Low	Low	High	Moderate	Moderate	Severe	High	Low	Low
Landslide	Low	Severe	Severe	High	Low	Severe	Low	Low	Severe	Low
Avalanche	—	—	—	High	Moderate	High	—	—	—	—
Collapsible soil	Moderate	High	High	—	—	—	—	—	—	—
Rapid settlement	High	—	—	—	—	Moderate	—	—	—	—
Soil erosion	Moderate	Slight to Severe	Slight to Moderate	Moderate to Severe	Moderate to Severe	Moderate to Severe	Severe	Severe	Moderate to Severe	Severe

3.7.3 Environmental Consequences

3.7.3.1 Methods

The evaluation of the environmental impacts considers the engineering geology, constructibility, and severity rating of the geologic hazards and their effect on the safety, service, and mobility of the transportation facility.

As described in section 3.7-1, five degrees of severity make up the overall geologic hazard rating system: Severe, High, Moderate, Low, and Slight. A hazard should meet a majority, not necessarily all, of the criteria listed, and each criterion is weighted differently.

3.7.3.2 Impact Summary

In general, all of the build alternatives would have similar effects on existing geologic conditions. Therefore, slope design, stabilization, and geologic hazard mitigation requirements would be similar, with a few exceptions. The following sections discuss the common impacts for all of the build alternatives and describe the impacts unique to each specific alternative.

The No Action alternative would not directly affect existing geologic conditions. However, existing problems with slope erosion and geologic hazards would continue. Efforts to clean up deposited material after an event would be addressed by maintenance activities. Other forms of mitigation that would require engineered solutions must be prioritized along with other safety issues in the Corridor.

Table 3.7-1 summarizes the geologic conditions and hazards found in the Corridor. Current effects on existing conditions that would continue to exist under the No Action alternative are identified. Table 3.7-2 summarizes only the geologic conditions that would affect the specific build alternatives.

3.7.3.3 Impacts by Alternative

No Action

The No Action alternative would be directly affected in places by existing geologic conditions, as summarized in Table 3.7-1. The greatest hazards would be landslides, rockfall, avalanches, and debris flow/mudslides. To a lesser degree, potential effects of collapsible soils and rapid subsidence may occur.

Landslides would be an existing hazard in the following areas:

- In Dowd Canyon, the extent and severity of existing areas of slope instability could cause roadway closure and/or dam the river (in the event of an extensive landslide).
- Existing landslides on Vail Pass would continue to create roadway maintenance problems in isolated locations.
- The Floyd Hill rockslide is presently unstable, with ongoing movement and maintenance problems along the shoulder of the interstate.

Rockfall is an ongoing and severe hazard along the Georgetown Incline. Recent construction of three rockfall fences has provided limited mitigation. The vast majority of vehicle accidents related to rockfall in this area occur when a moving vehicle hits a rock in the roadway. Accidents associated with rockfall hazards also involve rocks hitting vehicles in the roadway. Very few rockfall events have resulted in injury or fatality. Existing rockfall maintenance would continue under the No Action alternative and would include running a blade on the road to remove smaller rocks and clearing rock catchment areas behind concrete barriers and ditches. In addition, individual contracts are awarded and implemented (based on funding and a system of identified priorities) to perform scaling and blasting as needed to minimize rockfall hazards. Other areas of concern for rockfall hazards would include rock excavations through Dowd Canyon and along US 40 through Mount Vernon Canyon. Some rocks that originate from cuts along US 40 roll on to I-70.

Debris flow/mudslides will continue to occur, with the potential to affect the highway. Areas most at risk would include Watrous Gulch, the multiple chutes near Georgetown Lake, and west of Silver Plume at the former town site of Brownville.

Presently, avalanches are mitigated by dispensing charges out of helicopters to trigger slides. However, in some cases avalanche control work fails and results in the roadway being covered by avalanches (triggered or natural), resulting in temporary road closures. This is especially true for the avalanche chutes west of the EJMT and on Vail Pass.

Ground subsidence from past mining has affected the highway at Hidden Valley and in Idaho Springs. The extent of this hazard is unknown at this time. Subsidence from historic tunneled mine workings would remain a hazard in these areas; further investigation would be needed to determine the extent of the openings.

Severe soil erosion would be prevalent in most of the geologic domains; however, its potential to disrupt or limit mobility would be much less than the impact from landslides, debris flows, and avalanches, which could cause closure of the highway. The severity of the soil erosion would depend on its reclamation potential and impact on water quality.

Adjoining Projects

Projects currently in development or under construction that would have no affected geology and soils resources would include the Eagle County Airport interchange, widening of SH 9, and Hogback parking facility. The only study for an adjoining project that may affect geologic conditions along the Corridor would be SH 119/Black Hawk Tunnel. Current alignments would require that I-70 be modified near the base of Floyd Hill to facilitate construction of the tunnel ramp connection. The ramps would likely require excavation into the base of the existing Floyd Hill rockslide. Mitigation alternatives considered to date may include a large excavation near the top of the slide to prevent movement or the placement of the ramp on structures to avoid the slide.

Minimal Action

Components of the Minimal Action alternative that would be affected by geologic conditions would include proposed interchange improvements, climbing lanes, and auxiliary lanes. Potential impacts would include the following.

Interchange Improvements

Improvements of the Minturn interchange (milepost 171) may be affected by the Whiskey Creek landslide complex. Previous interchange projects at this location experienced considerable delays and slope movements immediately after construction, resulting in highway closure.

Any modifications to existing highway geometry at the base of Floyd Hill could potentially disturb and mobilize the Floyd Hill rockslide.

Auxiliary Lanes

Climbing lanes in Dowd Canyon (mileposts 170 to 173) would be in an area where the dip of the bedding contributes to landslides and rockfall hazards. The current maintenance practice for rockfall runs would need to continue.

Climbing lanes on Vail Pass (mileposts 180 to 190) would be constructed in terrain affected by alpine glaciation. Extensive landslides persist here as a result of glacial events and poor rock quality. The highway widening for the additional lanes would require mitigation measures to stabilize potential slope failures.

Widening on the cut slope side of the highway along the west approach to EJMT (mileposts 215.3 to 218.3) may trigger large slope failures. Many slopes constructed during initial highway widening failed during construction, considerably delaying improvement projects. Embankment slope failures also are prevalent in this area; extensive mitigation would be required for potential slides and erosion control.

Construction of auxiliary lanes along the Georgetown Incline (mileposts 225.5 to 227.9) would require construction of large retaining walls (to support the highway) on the south side of the interstate. This would allow placement of the highway farther from rockfall hazards originating from slopes to the north. The existing catchment area would need to be maintained and/or expanded.

Transit

Transit alternatives include Rail with IMC, AGS, and Dual-Mode or Diesel Bus in Guideway. The alignment for the Rail with IMC and the AGS would essentially be the same; however, the on-grade Rail with IMC would be more susceptible to geologic hazards than the elevated AGS. The Bus in Guideway alternatives would encounter the same geologic conditions as Rail with IMC. The difference in impacts between Rail with IMC and Bus in Guideway alternatives would be due to the bus guideway placement in the median. Discussion of environmental consequences primarily compares the platform width requirements and on-grade versus elevated sections of the transit systems.

Avalanche

The Transit alternatives would pass through avalanche areas on the west side of Vail Pass, through Tenmile Canyon, along the Straight Creek approach to EJMT, at both portals of EJMT, and the base of Mount Bethel. These alternatives would not increase exposure to these hazards more than the No Action or other proposed alternatives, except for the location of a new tunnel bore to cross through the Continental Divide. North and south bore alignments would pass beneath the more active avalanche chutes that originate from the Continental Divide and Coon Hill to the west of the west portals.

Debris/Mudflow

Few feasible methods of mitigation would be available for the debris flows that occur in Dowd Canyon, over Vail Pass, in Watrous Gulch, and in the Georgetown Lake and Bakerville to Silver Plume areas. Debris flows are likely to continue to deposit material on the highway. The current practice of maintaining catchment areas and cleaning the highway after a flow would be inhibited more by a transit platform located in the median than by the Highway alternatives. In addition, much of the material from these events would flow across the highway, allowing for faster removal. Construction of a transit platform or raised rail bed with barrier separators would interfere with this process. The Transit alternatives could affect maintenance activities and operation of the Rail with IMC and Bus in Guideway alternatives. The elevated AGS would be affected the least by the debris flows, and the Rail with IMC would be affected the most.

Landslide

The area of impact on existing slides would be greatest for the Rail with IMC alternative because most slope failures occur on the Western Slope (Vail Pass) where the Rail with IMC alternative would extend farther than the Bus in Guideway and Highway alternatives. The Rail with IMC alternative would cross several active landslides: the Vail Pass slides, Straight Creek slides, and Floyd Hill rockslide. In general, any type of rail system would require an immobile platform and would not accommodate large slope movements.

The most susceptible area would be a rail platform (either elevated or on-grade) constructed on the south side of I-70 along the Straight Creek approach to EJMT. Large embankments constructed during the original interstate program show signs of instability and may adversely affect the Rail with IMC alternatives.

All alternatives would include a new tunnel bore to the Continental Divide. The new bore on the north side of the existing EJMT would need to be designed to avoid the existing landslide that was activated during construction of the westbound bore. The cut-and-cover section at the east portal would require extensive stabilization due to the height of the cuts and relative poor conditions of the subsurface material and fractured bedrock.

Transit alternatives constructed from the east portal of the EJMT (milepost 215) to C-470 (milepost 260) would be affected by the Floyd Hill rockslide.

Rockfall

Rockfall is the most prevalent geologic hazard along the Corridor. Many rock slope stability hazards stem from the original designs of both I-70 and US 6. The most active area is along the Georgetown Incline. Any widening done to accommodate a transit platform must be constructed away from the north slopes to avoid increasing exposure to the hazard. High-severity rockfalls are also located at Dowd Canyon, at Vail Pass, at the Straight Creek approach to the west portal of EJMT, and around the Twin Tunnels.

Rock excavations and resulting construction disturbance would be lowest for Transit alternatives compared to Highway and Combination alternatives.

Soils

Soils that are severely susceptible to erosion are found along the west approach to EJMT and the Georgetown Incline. The stringent erosion control programs applied to recent highway construction projects such as Berthoud Pass, Wolf Creek Pass, and EJMT have successfully mitigated these impacts.

Six-Lane Highway 55 mph

The area of impact for the various categories under the geologic resources do not differ for the area affected by the different Highway alternatives through Clear Creek County. The proposed structured lanes through Idaho Springs would have no substantial impact on the geologic resource issues. Impacts for Highway alternatives are as described below.

Widening the highway to six lanes in its present location would encounter the greatest number and severity of geologic hazards of the three alternatives proposed for Dowd Canyon. Table 3.7-2 summarizes the potential effects of widening the highway without a tunnel. Between west Vail and Dowd Canyon, the only ways to widen the highway would be to cut further into the bluffs on the north side of the road or to place the additional lanes on cantilever, bridge, or wall sections along the south side. Conflicts with the proposed transit alignment would make this difficult or infeasible.

Avalanche

The Mount Bethel avalanche has been mitigated with snow fences and explosive charges dropped at the starting zone. No other avalanche hazards are located in the affected domains for the Six-Lane Highway 55 mph alternative.

Debris/Mudflow

The area of disturbance in the active debris flow locations near Georgetown Lake (mileposts 227 to 231) is near the greatest for all capacity improvement alternatives. Additional excavation into the adjacent slope would reduce the available retention area for the debris flow material, and a median barrier would inhibit its removal from the highway.

Landslide

After crossing the Eagle River Bridge at Dowd Canyon, the present road traverses the toe of the Whiskey Creek landslide complex for more than 2,000 feet. To avoid cutting further into the toe, any widening must be done on the westbound side of the road. Because US 6 is located under the highway with steep slopes and a narrow distance between the two alignments, any added lanes must be cantilevered or supported on a wall or bridge.

After passing the Dowd No. 1 and No. 2 slides (Figure 3.7-1), the road passes the toe of the Whiskey Creek slide. At the midpoint of the toe, the space available is so narrow that only the present I-70 template and US 6 can be accommodated between the river and the slide. To avoid cutting into the slide, it may be necessary to sacrifice the interstate median, which begins where the road starts to pass the toe. One failure already has occurred in the backslope directly above this location.

After crossing the Eagle River Bridge at Eagle-Vail, the highway crosses an alluvial fan derived from the Eagle Valley Formation where collapsible soil exists. To date, the existing road has not experienced problems at this location.

The Floyd Hill rockslide is located near the bottom of the hill near the junction with US 6. In conjunction with the study for the proposed Black Hawk Tunnel, a preliminary geotechnical investigation was conducted to determine the surface extent and depth of this rockslide (HP Geotech 2001). Based on the information gathered, excavation at the toe of the slide would adversely affect current slide stability.

Rockfall

During I-70 construction, several large, steep rock cuts were made between the West Vail interchange and Dowd Canyon. The bedrock in this area contains numerous fractures and zones of weaker rock that have contributed to major rockfalls onto the highway. No fatalities or injuries have resulted from these failures, but westbound lanes have been closed for hours on several occasions. Individual rocks fall frequently, and the roadside ditch is too narrow to provide an adequate catchment area.

Enlarging the existing cuts on the north side of I-70 without extensive mitigation measures would increase the rockfall hazard. Potential measures would include rock bolts, wire mesh, cable netting, and shotcrete. Although mitigation would minimize the risk of rockfall and partially slow the erosion process, slope failures would continue to occur in this area.

The hillsides along the section to be widened through Clear Creek County are some of the most active rockfall sites in the state. The area of disturbance in the active rockfall zones would be among the largest for the Six-Lane Highway 55 mph alternative, and the resulting impacts would rank as severe. Rock catchments, rockfall mesh, and rockfall fences would be required to mitigate potential effects of this hazard.

The alignment for this alternative would have to be adjusted in the Georgetown Hill area to minimize the effect of rockfall on the proposed highway platform. Completely eliminating this hazard would not be feasible; however, attempts could be made to retain some of the rockfall material.

Six-Lane Highway 65 mph

In general the geologic hazards would be the same as those for the Six-Lane Highway 55 mph alternative, except at Dowd Canyon and Floyd Hill. At Dowd Canyon, the proposed tunnel would avoid many of the geologic hazards and would provide a safer highway condition than the No Action and all other alternatives.

The Six-Lane Highway 65 mph roadway template at Floyd Hill would include wider curves, but because the alternative bypasses the slide by placing the eastbound lanes in a new three-lane tunnel, resulting impacts from rockslides would be low.

Reversible/HOV/HOT Lanes

The Reversible/HOV/HOT Lanes alternative would use a roadway width similar to that of the Six-Lane Highway 55 mph alternative through Clear Creek County. The area of disturbance and related impacts for this alternative would be the same as those for the Six-Lane Highway 55 mph, discussed above.

Combination

Due to the wider platform required to accommodate the various systems, the Combination alternatives would disturb a larger area of geologic hazards than the Highway-only alternatives would.

Avalanche

The Combination alternatives would pass through avalanche areas located at the base of Mount Bethel, both portals of the EJMT, along the Straight Creek approach to the EJMT, through Tenmile Canyon, and on the west side of Vail Pass. Exposure to these hazards would be no greater than for any other alternatives including the No Action alternative, except for the location of a new tunnel bore through the Continental Divide. A north bore alignment would pass vehicles beneath an active chute west of the existing west portal. In their current configurations, these avalanches do not reach the highway. However, excavation near the base may expose additional hazards.

Debris/Mudflow

The I-70 median would be used as a catchment area for removal of debris/mudflow from the highway when necessary. The Bus in Guideway proposed within the median would impede this effort. An elevated platform, as required for AGS and a portion of the Rail with IMC alternative, may allow for faster removal of material.

Landslide

The area of impact on existing slides would be larger for the Combination alternatives than for other alternatives. Most of the active landslides are located on the Western Slope where the Transit portion of Combination alternatives would extend. The Combination alternatives would cross several active landslides, including the Floyd Hill rockslide, the Straight Creek slides, and the Vail Pass slides. In general, rail transit would require an immobile platform and would not accommodate large slope movements.

The most susceptible area would be a transit platform (either elevated or on-grade) constructed on the south side of I-70 along the Straight Creek approach to EJMT. Large embankments built during original highway construction show signs of instability that may adversely affect the transit portion of Combination alternatives.

Rockfall

The domains represented along the section of highway through Clear Creek County proposed for widening would be some of the more active rockfall sites in the state. The area of disturbance in the active rockfall zones would be among the largest for Combination alternatives. Rock catchments, rockfall mesh, and rockfall fences would be required to mitigate potential effects of this hazard.

The alignment for the Combination alternatives would have to be adjusted in the Georgetown Incline area to minimize the effect of rockfall on the proposed highway platform. The transit platform would be constructed along the south embankment away from the north slopes to avoid increasing exposure to the hazard. It would not be feasible to completely eliminate the hazard from rockfall, only to try to prevent some of the material from reaching the traveled roadway.

Tunnel Improvements

Dowd Canyon

Constructing both lanes of a widened interstate in a tunnel to bypass Dowd Canyon would avoid many but not all potential problems. A wider template would be required between west Vail and the east portal location, and a large rock excavation could increase the exposure to rockfall hazards.

Between the west portal location and the proposed Eagle River Bridge, the road would be on a short section of pavement that may require some cutting into the adjacent hillside. Across the bridge, the road would join the present alignment a few hundred feet from the west edge of the toe of the Whiskey Creek landslide.

As discussed in section 3.7.2.4, the Whiskey Creek landslide complex is on the state's landslide priority list due to the potential loss of service to I-70 and potential damming of the Eagle River. The proposed tunnel alignments would avoid all active landslides in the area.

If the existing roadway is kept open for local traffic beyond the east portal location, it could be reduced to a two-lane facility following the present eastbound lanes. Present westbound lanes could be used as a catchment area for future rockfall events.

Continental Divide

The north alignment for the tunnel proposed for the Six-Lane Highway 65 mph alternative at the EJMT would be designed to avoid the East Portal landslide. If the final alignment passes through the toe of the slide, as it did for the original EJMT complex, a buttress would be required and additional evaluation of the effect on the existing tunnels must be done. Because the general condition and overall stability of the East Portal landslide are uncertain, effects on proposed north bore tunnel alignments cannot be precisely determined.

Twin Tunnels

Potential rockfall hazards from the adjacent hillside could be mitigated with a new portal design, which would include extending the portal structure away from the slope.

Clear Creek Canyon Tunnels

Many existing rockfall hazard locations in Clear Creek Canyon between Idaho Springs and the base of Floyd Hill would be avoided by constructing these tunnels as proposed in the Six-Lane Highway 65 mph alternative.

3.7.4 Mitigation Measures

3.7.4.1 Previous Projects

I-70 has undergone numerous modifications since it was first built. Many early projects did little or nothing to mitigate geologic hazards and soil erosion in areas of these I-70 projects. In fact, the design of many early projects exposed some natural hazards. Design features in recent projects such as Glenwood Canyon, Vail Pass, and Berthoud Pass have mitigated geologic hazards and soil loss. Excavation and landscaping techniques were used to minimize soil loss and reverse existing erosion problems. In addition, roadway geometry on these projects was designed to minimize slope excavation and follow much of the natural topography.

On the Glenwood Canyon project, excavations used a new technique called rock sculpting**,** which involves blasting rock by using the existing rock structure to control overbreak and blast damage. This technique creates a more natural-looking cut and has been used on other projects throughout the western US.

Some I-70 projects have remediated erosion problems and geologic hazards that resulted from the original design of I-70. The Straight Creek erosion control projects along the west approach to the Continental Divide mitigated soil loss originating from the oversteepened cut slopes. Rockfall mitigation projects and scaling programs have been implemented at several locations, including Dowd Canyon and the Georgetown Incline. At the latter, mitigation measures specifically address rockfall from the cut slope and area of disturbance from the original highway construction. After consideration of numerous mitigation designs at the Georgetown Incline, CDOT has determined that fencing is the most practicable technique for the protection of the traveling public.

The original construction of EJMT produced approximately 1million cubic yards of excavated material that was disposed of at various locations surrounding the site. A large portion of material was placed as fill in the I-70 embankments at both approaches to the tunnels. Some material was also placed in two disposal sites in the Arapaho and Roosevelt National Forests along the north side of the highway approximately 1 to 2 miles east of the tunnel. Suitable remaining material was crushed and used as aggregate in the concrete placed in the lining and other structural portions of the tunnels.

3.7.4.2 Mitigation of Alternatives

Excavations in rock and soil would cause both temporary impacts from construction activities and long-term impacts associated with achieving and maintaining slope stability. Slopes constructed in rock must be safe from rockfall and large-scale slope instability during construction and operation. Design of these slopes must consider the variable and complex geologic conditions encountered along the Corridor through the affected domains.

Transit platforms constructed in the Gore Mountain Range domain and along Straight Creek would require considerable stabilization of landslides to ensure a stable operating platform. Possible mitigation measures would include retaining structures, buttresses, slope geometry modifications, and drainage enhancements.

Table 3.7-2. Potential Geologic Conditions and Severity Index for Capacity Improvement Alternatives

Geologic Hazards	Minimal Action Alternative	Transit Alternatives				Highway Alternatives			Combination Highway /Transit Alternatives			
		Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	6-Lane Highway 55 mph	6-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	6-Lane Highway with Rail and IMC	6-Lane Highway with AGS	6-Lane Highway with Dual-Mode Bus in Guideway	6-Lane Highway with Diesel Bus in Guideway
Adverse faulting		Moderate: Unstable slope conditions for rail transit platform at Tenmile Canyon, Straight Creek	Moderate: Unstable slope conditions for rail transit platform at Tenmile Canyon, Straight Creek	Moderate: Unstable slopes at Straight Creek, Dumont to Idaho Springs, active rockslide at Floyd Hill	Moderate: Unstable slopes at Straight Creek, Dumont to Idaho Springs, active rockslide at Floyd Hill	High: Areas of unstable slopes Fall River to Floyd Hill (mp 237.4, 242.3–242.7, 243.3–245.1)	Low: Tunnels would avoid many of the geologic hazard areas	High: Areas of unstable slopes Fall River to Floyd Hill (mp 237.4, 242.3–242.7, 243.3–245.1)	High: Same as Rail with IMC	High: Same as AGS	High: Same as Six-Lane Highway (55 mph)	High: Same as Six-Lane Highway (55 mph)
Adverse rock structure	Severe: Auxiliary lanes EJMT to Herman Gulch	High: Unstable slopes for rail transit platform at Dowd Canyon, Tenmile Canyon, Straight Creek	High: Unstable slopes for rail transit platform at Dowd Canyon, Tenmile Canyon, Straight Creek	Moderate: Unstable slopes at Straight Creek, Dumont to Idaho Springs, Floyd Hill	Moderate: Unstable slopes at Straight Creek, Dumont to Idaho Springs, Floyd Hill	Moderate: Unstable slopes at Dumont to Idaho Springs, Floyd Hill	Low: Tunnels would avoid many of the geologic hazard areas	Moderate: Unstable slopes at Dumont to Idaho Springs, Floyd Hill	High: Same as Rail with IMC	High: Same as AGS	Moderate: Same as Bus in Guideway	Moderate: Same as Bus in Guideway
Poor rock quality	Severe: Auxiliary lane EJMT to Herman Gulch	High: Metamorphic rocks interbedded with shale and sandstone west of Wheeler Junction cause unstable slopes and rockfall	High: Metamorphic rocks interbedded with shale and sandstone west of Wheeler Junction cause unstable slopes and rockfall	High: Slope failure on steep slopes with poor rock quality along Straight Creek	High: Slope failure on steep slopes with poor rock quality along Straight Creek	Low to Moderate	Low to Moderate	Low to Moderate	High: Same as Rail with IMC	High: Same as Rail with IMC	High: Same as Bus in Guideway	High; Same as Bus in Guideway
Debris flows	High: Interchange Silver Plume, auxiliary lane Silver Plume to Georgetown Severe: Auxiliary lane Bakerville to EJMT	High: Debris flows could affect operations at Dowd Canyon, West Vail Pass, Watrous Gulch, Silver Plume and Georgetown Lake	Low: Debris flows may pass under elevated structure for AGS	High: Debris flows could affect operations at Watrous Gulch, Silver Plume, and Georgetown Lake	High: Debris flows could affect operations at Watrous Gulch, Silver Plume, and Georgetown Lake	High: Debris flows could affect operations at Watrous Gulch, Silver Plume, and Georgetown Lake	High: Debris flows could affect operations at Watrous Gulch, Silver Plume, and Georgetown Lake	High: Debris flows could affect operations at Watrous Gulch, Silver Plume, and Georgetown Lake	High: Same as Rail with IMC	High: Same as Six-Lane Highway (55 mph)	High: Same as Bus in Guideway	High: Same as Bus in Guideway
Rockfall	Severe: Auxiliary lane Silver Plume to Georgetown (in the area of the Georgetown Incline), Curve safety modification Dowd Canyon	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Low to High: Rock may pass under elevated structure for AGS or could hit the structure causing structural damage	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline	Severe: Most prevalent hazard in the Corridor. Most active area is Georgetown Incline
Landslide	Severe: Auxiliary lane Silver Plume to Georgetown, Curve safety modification Dowd Canyon	Severe: Transit operations would require a stable base that could be affected by active slides at Vail Pass, Straight Creek, and Floyd Hill	Severe: Transit operations would require a stable base that could be affected by active slides at Vail Pass, Straight Creek and Floyd Hill	Severe: Guideway could affect runout area and maintenance operations at Straight Creek and Floyd Hill	Severe: Guideway could affect runout area and maintenance operations at Straight Creek and Floyd Hill	High: Active slides at Dowd Canyon and Floyd Hill	Low: Tunnel proposed for Six-Lane Highway 65 mph alternative would avoid slide areas at Dowd Canyon and Floyd Hill	High: Active slides at Dowd Canyon and Floyd Hill	Severe: Same as Rail with IMC	Severe: Same as AGS	Severe: Same as Bus in Guideway	Severe: Same as Bus in Guideway
Avalanche	Moderate: Bakerville to EJMT	High: Avalanche areas at west Vail Pass, Tenmile Canyon, Straight Creek could affect rail operations	High to Low: Depending on severity, avalanche may flow beneath elevated structure with no impact on operations	Moderate: Avalanche areas at Straight Creek may affect operations	Moderate: Avalanche areas at Straight Creek may affect operations	Low: Mitigation measures at Mount Bethel would minimize avalanche hazard	Low: Mitigation measures at Mount Bethel would minimize avalanche hazard	Low: Mitigation measures at Mount Bethel would minimize avalanche hazard	High: Same as Rail with IMC	High to Low: Same as Six-Lane Highway (55 mph)	Moderate: Same as Bus in Guideway	Moderate: Same as Bus in Guideway

3.7.4.3 Tunnel Waste

Construction of tunnels would create large quantities of waste rock. CDOT would use waste materials onsite wherever possible. Onsite uses of rock and clayey materials would minimize truck traffic and disposal fees, in addition to avoiding environmental effects of transportation and disposal. Onsite uses might include having onsite crushers and concrete or asphalt plants for the creation of aggregate and riprap. These materials might be used for drainage channels, avalanche chutes, rockslide stabilization, berms, and road base. If onsite use is not possible or feasible, numerous disposal options have been identified below. Mitigation and handling of tunnel construction wastewater/process water is discussed in section 3.4, Water Resources.

Several mining operations, located in Eagle, Summit, Clear Creek, and Jefferson counties, were contacted about the potential for storage, resale, or disposal of this waste rock. These operations likely would be active (although possibly in final reclamation phase) 20 to 30 years in the future. The *Waste Rock Management for Tunnel Construction* (Huyck 2002) contains more details on waste rock management, including potential temporary storage, resale, or disposal sites. (Note that costs listed here reflect current charges, not net present value.)

Private operations were considered for waste rock management. Although a borrow pit located on USFS land was considered, the site was dismissed due to possible environmental effects. Three types of waste rock have been considered: hard rock that could be processed and resold, hard rock that would be too large to reprocess, and clayey or crumbly material that could not be sold. Table 3.7-3 lists the locations where material originates, the maximum amount of waste to be generated, and the rock type to be generated.

If tunnel construction waste material is excavated on USFS lands and transported off USFS lands for either disposal or to private vendors who, in turn, sell the material, then CDOT would be required to purchase the mineral material through a common minerals permit with the USFS. If the excavated mineral material is used as part of a project alternative or another CDOT project located on USFS lands, then no payment would be required to use the mineral material. If the excavated mineral material would be used on another public project (for example, fill for a school foundation), then CDOT could apply for a free-use permit and would not be charged for using the material on the public project (see existing Memorandum of Understanding (MOU) between FHWA, CDOT, BLM, and the USFS relative to management of the state transportation system through public lands for additional information/clarification). The MOU contains a price list for mineral materials on USFS lands, and this will be considered to support site-specific cost estimates and waste rock management strategies in Tier 2 studies.

Table 3.7-3. Tunnel Construction Waste

Waste Source	Location (mp on I-70)	Amount of Waste (cubic yard)	No. of Truckloads[a]	Rock Type
Dowd Canyon	169–173	973,520	74,887	Sand/shale
Continental Divide – north[b]	213.5–215	1,221,810	93,986	¾ hard granite/gneiss, ¼ clay or crumbly material
Continental Divide – south[b]	213.5–215	1,054,450	81,112	¾ hard granite/gneiss, ¼ clay or crumbly material
Twin Tunnels	242.1–242.3[a]	95,450	7,343	Hard granite/gneiss
65 mph curves – eastbound	242–242.8[a]	204,540	15,726	Hard granite/gneiss
– westbound	242–242.8[a]	470,430	36,187	Hard granite/gneiss
Floyd Hill Tunnel	243.2–245.2	756,770	58,214	Hard granite/gneiss

[a] For Six-Lane Highway (55 or 65 mph) or Rail with IMC alternatives, options would include either increasing the bores at the Twin Tunnels or creating 65 mph curve tunnels that would pass around the existing Twin Tunnels.
[b] The total for the Continental Divide borings would be 2,276,260 cubic yards. Since one-fourth of this material is estimated to be crumbly or clayey, the amount of material unlikely to be resold would be about 569,070 cubic yards.
+Assumes 13 cubic yards per truckload, rounded to next truckload.

Mining and Quarrying

All of the operations that were contacted expect to be in operation or in final reclamation for the timeframe noted above. All operators note that their mining permits can either include this material or require minor modifications to their permits. Two operations would require either permit modifications or paving new acceleration/deceleration lanes to handle the increased truck traffic.

Generally, private operations in each county would accept any clean, hard rock that is less than 2 feet in diameter. Because this material could be crushed and resold, no tipping fees would be charged as long as the material is trucked to the crusher site. The size requirement should be achieved during tunnel excavation for most material removed. One site would accept clean hard rock less than 1 foot in diameter for crushing. For material that exceeds the size limit, it could be stockpiled for sale as riprap at some locations or disposed onsite at others. This would incur a tipping fee (ranging from $0.75 to $1.93 per cubic yard) or an undetermined handling fee. For the hard material from all sources except Dowd Canyon, several large operations could handle the waste rock, whether for processing, disposal, or both. If all of the hard waste rock from the Continental Divide and east were disposed of, instead of processed and resold, costs for tipping fees would range from $2,346,360 (for 3,128,480 cubic yards with Twin Tunnels option at $0.75 per cubic yard) to $7,156,440 (for 3,708,000 cubic yards with the 65 mph tunnels option at $1.93 per cubic yard).

For the crumbly material that is expected from the eastern portion of the Continental Divide, some sites would accept the material for a tipping fee, but others would not. Tipping fees for the clayey material would range from $426,000 to $1,098,310.

For the sandstone/shale from the Dowd Canyon location, the volume noted would be three times the annual production at each of two operations contacted. One operation would accept only material that is suitable for reprocessing; the other would only dispose of the material. Both sites would charge for stockpiling or materials disposal. An estimate of this cost would be $730,000 for disposal/stockpiling of the Dowd Canyon material.