FINAL REPORT

I-70 Mountain Corridor Design Speed Study

Prepared for

COLORADO Department of Transportation

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Contents

Acronyms and Abbreviations

AGS	Advanced Guideway System
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
Corridor	I-70 Mountain Corridor
CSS	Context Sensitive Solutions
FHWA	Federal Highway Administration
I-70	Interstate 70
ITS	intelligent transportation systems
LOSS	Level of Service of Safety
MP	milepost
mph	miles per hour
PLT	Project Leadership Team
NEPA	National Environmental Policy Act
PBPD	Performance-Based Practical Design
PEIS	*I-70 Mountain Corridor Programmatic Environmental Impact Statement* (CDOT, 2011a)
ROD	*I-70 Mountain Corridor Record of Decision* (CDOT, 2011b)
US	United States Highway
U.S.C.	United States Code
VSL	variable speed limit

SECTION 1

Introduction

Travel speeds in the Interstate 70 (I-70) Mountain Corridor (Corridor) are influenced by roadway geometry and other physical constraints, such as the proximity of streams to the road, which may restrict the centerline geometry; canyon walls that influence drivers to adjust their speeds; or vertical grades that hamper the operating speeds of some vehicles, particularly large trucks. Selecting a design speed for a project or roadway segment must consider all of these factors, as well as continuity with adjoining roadway segments, length of the project, and distance between physical constraints. The I-70 Mountain Corridor Context Sensitive Solutions (CSS) Design Guidelines aim to connect and integrate different projects within the Corridor, and appropriate design speeds must be determined holistically to integrate with adjoining projects (Colorado Department of Transportation [CDOT], 2015a).

This I-70 Mountain Corridor Design Speed Study encompassed a Corridor-wide review of design speeds, identified issues, and recommended decision-making criteria and a design speed vision for the Corridor. The objectives of the I-70 Mountain Corridor Design Speed Study project were to define:

- A design speed vision and recommendation for the entire Corridor
- Locations of speed concerns, such as areas of lower speeds or high speed differential
- A process and criteria by which future projects can assess tradeoffs of location-specific design speed decisions

A review of the traffic operations, roadway geometry, safety history, and environmental opportunities and constraints related to travel speeds was completed for the entire 144-mile Corridor to provide an overall understanding of the measureable influences of these factors on design speed. This study conducted a more detailed review of travel and design speeds in the locations where the *I-70 Mountain Corridor Programmatic Environmental Impact Statement* (CDOT, 2011a) (PEIS) Preferred Alternative approved roadway improvements that would require design speed decisions in future Tier 2 National Environmental Policy Act (NEPA) processes.

This study has determined—with stakeholder input—that most of the Corridor roadway improvements can and should be designed for 65 miles per hour (mph). However, in two isolated locations in the corridor—Floyd Hill through the Twin Tunnels east of Idaho Springs (milepost [MP] 242 to MP 247) and through Dowd Canyon west of Vail (MP 170 to MP 173)—a lower design speed is preferable. In these two locations, a lower design speed meets the purpose and need for the project as well or better than the 65 mph design speed, and the 65 mph design speed alignments through these locations have higher environmental impacts and costs and are more complex and difficult to construct and maintain.

1.1 Why did CDOT conduct this study?

In 2011, the Federal Highway Administration (FHWA) signed the *I-70 Mountain Corridor Record of Decision* (CDOT, 2011b) (ROD) approving the Preferred Alternative for the PEIS. The decision approved a broad (Tier 1) program of transit, highway, safety, and other improvements on the 144-mile route between Glenwood Springs and the western edge of the Denver metropolitan area. The decision provides a framework for CDOT to implement specific projects in the Corridor as funding allows. To carry out improvements outlined in the Tier 1 decision and that have federal involvement, subsequent NEPA processes, referred to as Tier 2 NEPA processes, are required.

A design speed decision will help streamline implementation of projects in speed-constrained areas of the Corridor.

The PEIS evaluated alternatives for a 55 mph design speed and a 65 mph design speed. The ROD did not select a preferred design speed but rather left both options available for future Tier 2 processes. The ROD specified that either a Tier 2 NEPA process would need to be completed to identify a Corridor-wide design speed or that site-specific Tier 2 NEPA processes in areas of constrained speeds would need to consider alternatives with both 55 mph and 65 mph design speeds. Because CDOT is currently considering potential interim and permanent improvements within speed-constrained areas, CDOT and FHWA determined that addressing design speed Corridor-wide now would be beneficial. A design speed decision will provide consistency for future projects, and ensure that site-specific designs in areas where design speeds are constrained do not restrict or create impacts for future projects outside the geographic limits of the constrained areas, and streamline future Tier 2 NEPA and design processes.

1.2 What is the relationship of this study to the PEIS?

This I-70 Mountain Corridor Design Speed Study focused on those areas of the Corridor where the PEIS Preferred Alternative proposes roadway improvements, as these are the locations where future Tier 2 NEPA projects will need to define a design speed. Although this study falls under a Programmatic Categorical Exclusion that does not require detailed NEPA documentation, this report serves to document the design speed Tier 2 decision stipulated in the ROD.[1] This study supplements the ROD by clarifying the PEIS Preferred Alternative design speed decision(s).

1.3 What is the context for travel speeds in the corridor?

Travel speeds in the Corridor are variable, ranging from lower than 50 mph to higher than 75 mph. Travel speeds are influenced by physical conditions and drivers' behaviors in both free flow and congested conditions. The project team compiled, mapped, and evaluated posted and prevailing speeds along the Corridor (**Exhibit 1**). In most locations where the PEIS Preferred Alternative includes roadway improvements, prevailing speeds are equal to or often less than posted speeds, meaning that even in free flow conditions, drivers are traveling at or below the speed limit. This condition is likely caused by horizontal and vertical aspects of the I-70 roadway (steep grades, tight curves) that influence drivers to slow their speeds under ideal travel conditions. Driver comfort levels and operating speeds reduce further in heavy traffic flow and/or adverse weather

[1] 23 Code of Federal Regulations (CFR) 771.117(c)(1) **Activities which do not involve or lead directly to construction, such as planning and technical studies**; grants for training and research programs; research activities as defined in 23 United States Code (U.S.C.) 307; approval of a unified work program and any findings required in the planning process pursuant to 23 U.S.C. 134; approval of statewide programs under 23 CFR part 630; approval of project concepts under 23 CFR part 476; engineering to define the elements of a proposed action or alternatives so that social, economic, and environmental effects can be assessed; and Federal-aid system revisions which establish classes of highways on the Federal-aid highway system.

conditions. The influence of these factors produces turbulence in the traffic flow (particularly during peak travel times) as drivers react to conditions and adjust their operating speeds.

Two locations in the Corridor – Dowd Canyon (approximately MP 170 to MP 173) and Floyd Hill through the Twin Tunnels (approximately MP 242 to MP 247) – were focus areas of the design speed decision because the roadway template and alignment varies with a 55 mph or 65 mph alternative. These areas are shown in **Exhibit 1**, and Section 2 of this report explains the design variations in these focus areas and why they were evaluated separately.

Speed differentials between passenger vehicles and heavy trucks are notable in many locations in the Corridor where steep grades or tight horizontal curves affect truck operations. Truck speeds are 10 mph to more than 20 mph lower than prevailing passenger car speeds (**Exhibit 2**), and wide speed variations create turbulence in the traffic flow and pose safety and mobility issues.

1.3.1 What are design speeds, posted speeds, and prevailing speeds?

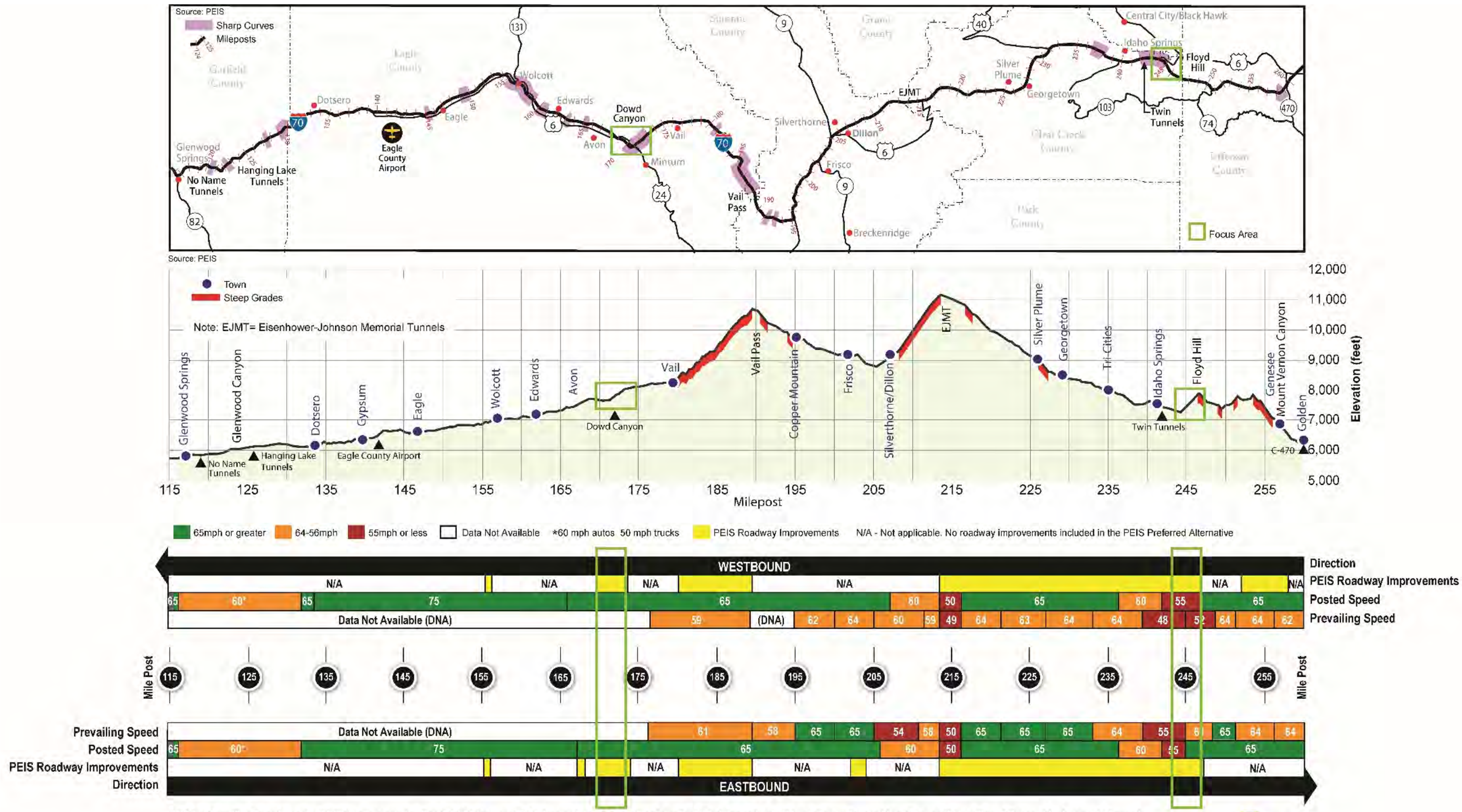
The terms design speed, posted speed, and prevailing speed each refer to a specific aspect of roadway design and traffic operations. These terms are defined as follows:

Design speed — A selected speed used to determine the various geometric features of the roadway (FHWA, 2007a). The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, adjacent land use, and functional classification of the highway. Design speed is different from the other controlling criteria in that it is a design control, rather than a specific design element. In other words, the selected design speed establishes the range of design values for many of the other geometric elements of the highway. Because of its effect on so much of a highway's design, the design speed is a fundamental and very important choice that a designer makes. The selected design speed should be high enough so that an appropriate regulatory speed limit will be less than or equal to it. Desirably, the posted speed limit would be close to the speed at which drivers comfortably operate.

Posted speed — One of two speed limit types (statutory speed is other type); the maximum lawful vehicle speed for a particular location as displayed on a regulatory sign (FHWA, 2009b). Posted speeds are displayed on regulatory signs in speed values that are multiples of 5 mph.

Prevailing speed, or 85th-Percentile Speed — The speed at or below which 85 percent of the motor vehicles travel (FHWA, 2009a).

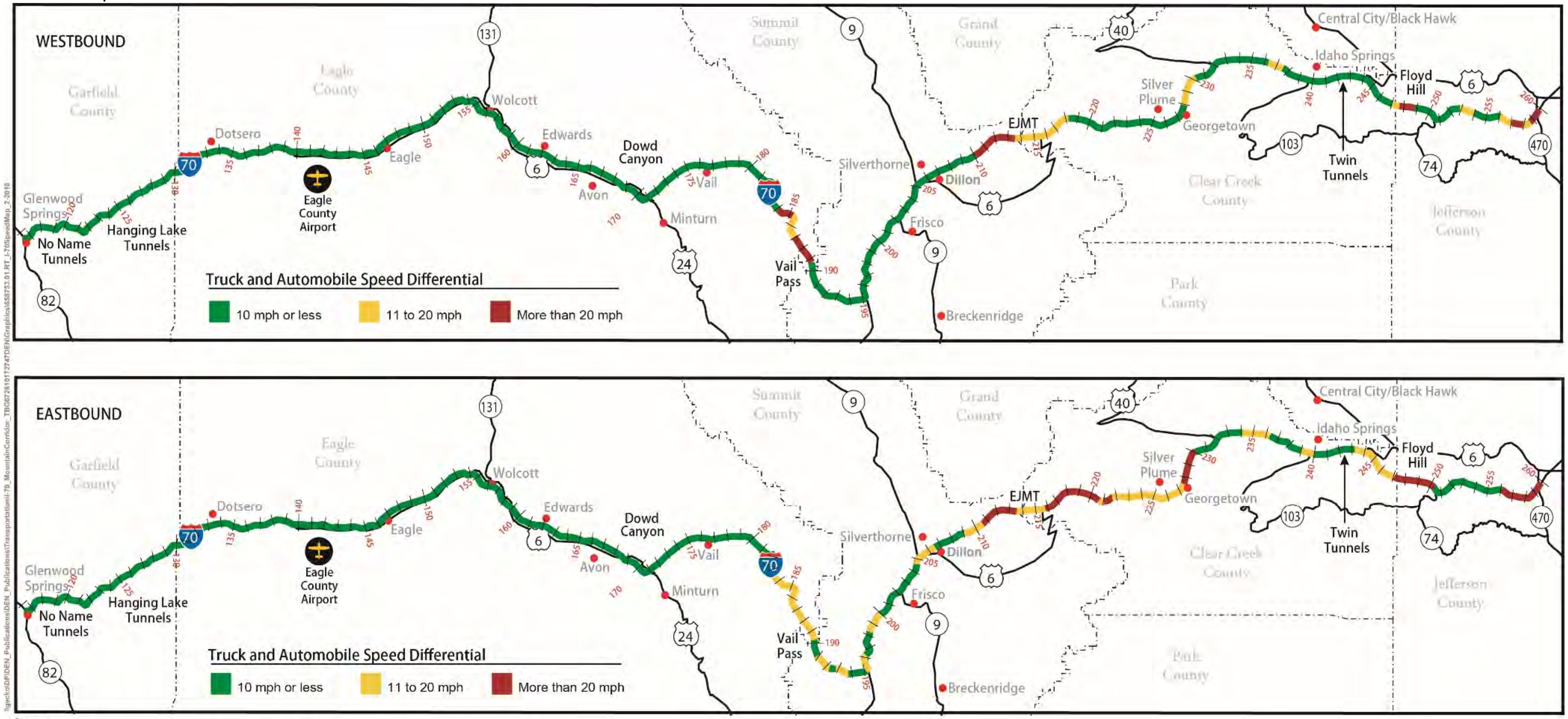
Exhibit 1: Locations of Horizontal and Vertical Constraints and the Relationship to Posted and Prevailing Speeds in the Corridor



DNA for Prevailing Speeds west of Vail Pass (apoproximatley MP 177) becuse CDOT does not maintain devices to collect this information in this portion of the corridor. Because this portion of the corridor has posted speeds greater than 65mph, the Glenwood Canyon speed limit would not be raised, and there are no plans to modify speed limits elsewhere, prevailing speed data were not readily available or relevant to the decisions in this study and were not compiled.

Focus Area

Exhibit 2: Speed Differentials between Trucks and Automobiles in the Corridor



Source
Truck Speeds: American Transportation Research Institute - National Corridors Analysis and Speed Tool (N-CAST)
Auto Speeds: Colorado Department of Transportation

1.3.2 How does design speed affect roadway design?

As noted in the definition, design speed is an important consideration for roadway designers. Design speed is one of 13 controlling criteria FHWA identifies as having substantial importance to the operational and safety performance of any highway (23 CFR 625). One of these criteria is Design Speed. Design Speed is a design control used to establish values for the other design elements. The other 12 controlling criteria are specific elements of the roadway template, such as travel lane or shoulder widths.

Roadway design geometry is largely controlled by the desired design speed. The horizontal and vertical alignments of the alternatives are evaluated by comparing them to the national and state guidance for highway geometrics. In recent years, FHWA has introduced the potential for more flexibility in applying the controlling criteria, and in 2015, presented proposed changes to the American Association of State Highway and Transportation Officials (AASHTO) Board of Directors. The goal of these changes is to give engineers more flexibility to use engineering judgement in applying and evaluating the criteria to improve safety and/or operations.

Along the same lines, many state Departments of Transportation are moving toward a Performance-Based Practical Design (PBPD) approach to meet both project and system objectives. The goal of PBPD is to deliver maximum value at a lower cost using a Design-Up approach. The traditional design approach used the FHWA controlling criteria, along with other pre-established constraints like right-of-way, topography, and environmental impacts, to layout out a solution that met the minimum criteria within the limits established. The Design-Up approach, encompassed within PBPD, first considers the purpose and need specifically of the transportation performance needs, but also considers environmental constraints. This approach considers cost versus the performance benefits of the particular design element.

The PEIS Preferred Alternative was developed in this spirit of flexibility. Its 50-year vision was established with an adaptive management approach for implementing improvements incrementally in response to changing conditions and trends.

1.4 How was the study conducted?

Led by a Project Leadership Team (PLT), this study was conducted over a 10-month period. The following tasks were performed (generally in the order listed) to identify existing conditions, refine and evaluate alternatives, and develop recommendations:

1. Compile and summarize relevant standards from:
    - I-70 Mountain Corridor Design Criteria (CDOT, 2009b);
    - State and federal criteria for design speed, including FHWA criteria for horizontal and vertical alignments (23 CFR 625) the AASHTO Green Book (AASHTO, 2011), and CDOT Design Criteria (CDOT, 2005); and
    - Safety studies and research on highway design speeds from AASHTO (AASHTO, 2005), National Cooperative Highway Research Program (NRCHP) (NRCHP, 2005 and 2014), and FHWA (FHWA, 2012a and 2012b).
2. Assess and summarize issues with design speeds, including the effect of variable speeds on safety and mobility, including travel times, in both peak and off-peak conditions.
3. Collect and analyze data:
    - Posted and prevailing speeds

- PEIS design files, traffic modeling, curve safety modification locations, and speed limit discussions
- I-70 Mountain Corridor Traffic and Revenue Study (CDOT, 2014).

4. Catalogue information about existing and future conditions.
5. Examine the components of the PEIS Preferred Alternative to determine issues, criteria, and performance measures influencing design speed decisions.
6. Collect and evaluate geometric data, including existing and future design conditions, in support of the defined performance measures.
7. Evaluate design speed effects on core values and criteria, recommend Corridor design speed(s), and identify mitigation measures related to travel speeds that may be considered by future Tier 2 processes.

The project team presented findings to the PLT at key milestones and carried their recommendations forward into subsequent project tasks. The team referenced and incorporated PEIS documentation for environmental issues/constraints and preliminary geometric layouts for the two design speeds. Updated information related to existing volume, speed, and crash conditions was provided by CDOT to assist with the evaluation of alternatives and development of recommendations. Appendix A contains a report that summarizes the existing conditions in the Corridor (with a focus in the locations of PEIS Preferred Alternative improvements), applicable industry and state standards, and results of other relevant studies previously completed in the Corridor.

1.5 How will the study's recommendations be incorporated into future Tier 2 processes?

This study's recommendations allow future Tier 2 processes to move forward without having to consider both a 55 mph and 65 mph design speed for roadway improvements. This study also provides considerations for mitigating effects of speed variations for future Tier 2 projects. Section 4 provide design and traffic mitigations and enhancements that should be considered for future Tier 2 roadway improvements, related to design speed throughout the Corridor and in the focus areas within the Corridor.

1.6 What is the I-70 Mountain Corridor CSS process, and how was it used on this study?

CSS is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety, mobility, and infrastructure conditions (FHWA, 2007b). The CSS approach considers the total context within which a transportation improvement project will exist. CSS principles include early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process.

The I-70 Mountain Corridor CSS process provides guidance developed specifically for the Corridor in collaboration with stakeholders. This guidance includes a 6-Step Decision Process, Design Criteria and Aesthetic Guidance, and a Context Statement and Core Values for the I-70 Mountain Corridor.

CDOT and FHWA have committed to use the I-70 Mountain Corridor CSS process on all projects on the I-70 Mountain Corridor. As described on the Corridor CSS website (https://www.codot.gov/projects/contextsensitivesolutions), all Tier 2 processes will use the I-70

Mountain Corridor CSS 6-Step Decision Process, include a PLT composed of stakeholders, and be guided by the Context Statement and Core Values developed specifically for each project.

This study established a PLT and followed the 6-Step Decision Process to reach a final recommendation. The first five steps of the 6-Step Decision Process were addressed through a series of PLT meetings (see Appendix B for meeting minutes).

The PLT's primary roles were to lead the project by providing relevant materials and data, champion the I-70 Mountain Corridor CSS process to ensure applicable guidance was integrated into the project, and enable decision making by identifying and implementing steps needed to resolve issues and propose solutions. The PLT membership consisted of representatives from FHWA, CDOT, and Corridor leaders representing the United States Forest Service, Colorado Motor Carriers Association, Colorado Ski Country USA, and Clear Creek, Eagle, and Jefferson counties. The PLT met with the project team four times during the course of the study to review project progress and offer recommendations.

- PLT Meeting 1 obtained endorsement of the study purpose, scope, and approach from the PLT, fulfilling the goals of *Step 1, Define Desired Outcomes and Actions* and *Step 2, Endorse the Process*.
- PLT Meeting 2 gathered input on alternatives evaluation criteria and performance measures, addressing *Step 3, Establishment of Criteria*.
- PLT Meeting 3 provided the results of the evaluation of the PEIS design speed alternatives and discussed the study's resulting design speed recommendations, fulfilling *Step 4, Develop Alternatives or Options* and *Step 5, Evaluate, Select, and Refine Alternative or Option*.
- *Step 6, Finalize Documentation and Evaluate Process* will be addressed through written communication, with the PLT providing review of the final report and input on the effectiveness of the I-70 Mountain Corridor CSS process.

Alternatives

The I-70 Mountain Corridor between Glenwood Springs and the western edge of the Denver metropolitan area is 144 miles long, with approximately 50 miles of highway improvements identified in the PEIS Preferred Alternative maximum program of improvements. These highway improvements consist of a combination of safety, capacity, operation, interchange, and auxiliary lane elements. These components are all encompassed in the Highway Improvements portion of the PEIS Preferred Alternative, and are approved in the ROD with two different design options: 55 mph and a 65 mph.

The 55 mph and 65 mph design options presented in the PEIS have been evaluated in this study as two different design speed alternatives: a 55 mph design speed alternative and a 65 mph design speed alternative. The two alternatives have the same typical section for most locations along the Corridor because the Corridor geometry supported a 65 mph design speed for both alternatives in most locations (in other words, the 55 mph design speed alternative supports a 65 mph design speed in most locations). There are only two locations in the maximum program of improvements where design presented in the PEIS is different for the 55 mph and 65 mph options: the safety and capacity improvements in Dowd Canyon (MP 170 to MP 173) and the six-lane capacity from Floyd Hill through the Twin Tunnels (MP 242 to MP 247). In these two locations, the PEIS 55 mph option has a 55 mph design speed, rather than 65 mph.

2.1 Where are design speed decisions relevant to planned roadway improvements?

Many of the elements identified within the PEIS Preferred Alternative can be implemented as proposed in the PEIS, regardless of design speed, because their design or implementation is unaffected by design speed decisions for the Corridor. These include all of the non-infrastructure components, the Advanced Guideway System (AGS) component, as well as the following highway improvements:

- Interchange improvements
- Truck operations improvements (pullouts, chain stations, emergency parking)
- Single-lane auxiliary lanes, because these occur in areas of the Corridor where the 55 mph and 65 mph design speed alternatives are the same (that is, they occur in locations where a 65 mph design speed is supported in both the 55 mph and 65 mph options)

The PEIS Preferred Alternative components that will be affected by design speed decisions are the following highway improvements located in the focus areas where the 55 mph and 65 mph options differ:

- Safety and capacity improvements in Dowd Canyon (MP 170 to MP 173)
- Six-lane capacity from Floyd Hill through the Twin Tunnels (MP 243 to MP 247)

2.1.1 What are the similarities between the 55 mph and 65 mph alternatives?

Except at Dowd Canyon and in the Floyd Hill area, the 55 mph and 65 mph alternatives propose the same alignment and typical section for improvements because the physical geometry of the Corridor accommodates a 65 mph design speed for added capacity, curve safety improvements, auxiliary lanes, interchange improvements, and truck operations improvements. In Dowd Canyon and Floyd Hill through the Twin Tunnels, the 65 mph alternative requires each direction to have independent alignments, some through tunnels, because the existing roadway curves around canyon walls too tightly to accommodate the higher 65 mph speed.

2.1.2 What are the location-specific differences between the alternatives?

In Dowd Canyon from MP 170 to MP 173, the two alternatives follow different alignments because of the physical constraints within the canyon. The 55 mph alternative is designed to a 55 mph design speed and follows the existing I-70 alignment in Dowd Canyon. The topographic constraints through the canyon eliminate the ability to construct a 65 mph alternative on the existing I-70 alignment, so the 65 mph alternative involves parallel 9,000-foot-long tunnels located north of the existing alignment.

The alternatives also differ from Floyd Hill through the Twin Tunnels (MP 242 to MP 247). The 55 mph alternative is designed to a design speed of 55 mph in this area, and both eastbound and westbound traffic remain on the existing I-70 roadway alignment. Like Dowd Canyon, topographic constraints in this area require two separate tunnels for the 65 mph alternative. The proposed 7,000-foot-long Floyd Hill tunnel would carry eastbound I-70 traffic only; westbound traffic would remain on the existing I-70 alignment, which can accommodate three lanes at a 65 mph design speed. The proposed 2,000-foot-long tunnel at Hidden Valley would carry westbound traffic only; eastbound traffic would remain on the existing I-70 alignment. **Exhibit 3** illustrates the tunnel locations in the Dowd Canyon and Floyd Hill through the Twin Tunnels areas.

2.1.3 How were the alternatives refined for this study?

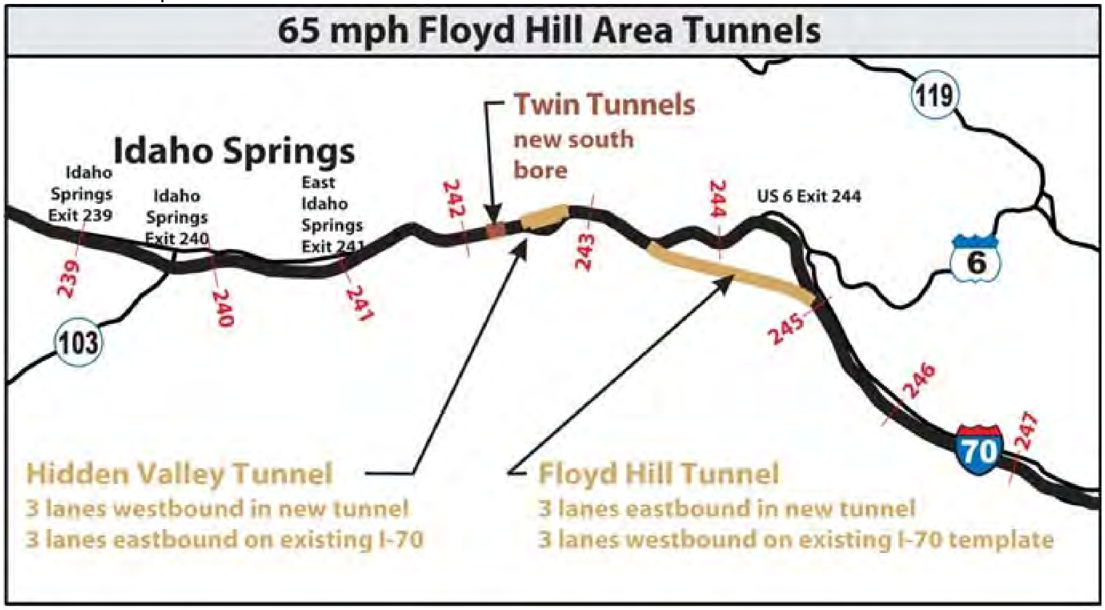
During the course of this study, both the 55 mph and 65 mph alternatives required supplemental details to accurately assess the physical impacts of the alternatives. In particular, the PEIS tunnel designs in the 65 mph alternative at both the Dowd Canyon and Floyd Hill through the Twin Tunnels focus areas were not developed enough to accurately compare the impacts associated with integrating and constructing new tunnels. Therefore, the following assumptions were included with the 65 mph design:

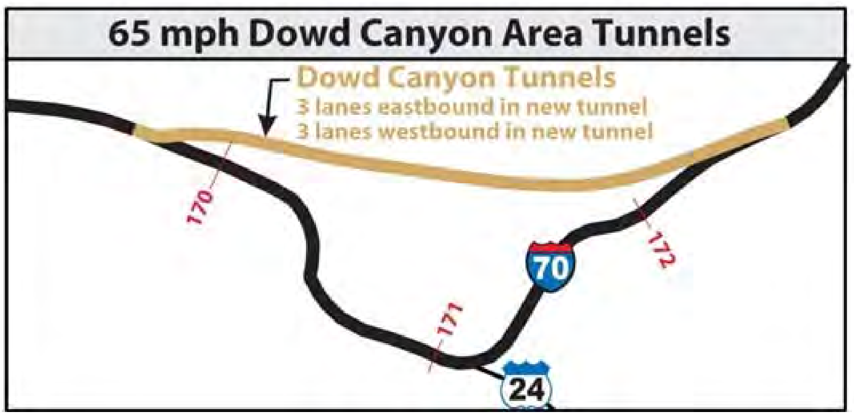
- The 65 mph alternative assumes that the existing I-70 alignment at Dowd Canyon will be maintained as an emergency bypass route during tunnel closures.
- The proposed parallel tunnels at Dowd Canyon bypass the existing interchange of I-70 with United States Highway (US) 24. A split interchange was added to the 65 mph alternative to provide access on both sides of the tunnel between the new I-70 alignment and the emergency bypass route and US 24 on the existing I-70 alignment.
- The proposed tunnel at Floyd Hill bypasses the existing interchange of I-70 with US 6. Interchange configurations at Floyd Hill will need to be investigated by future designers to maintain full access to and from US 6 in both directions of I-70, and to maintain emergency bypass routes for traffic during tunnel closures.

2.2 How were alternatives evaluated?

The two alternatives were evaluated against a set of measurable criteria relevant to the influence of design speed. The alternatives were rated using a good/fair/poor scale developed for each performance measure. In general, a good rating indicates that differences in the design speed would have minimal or positive influence on the performance measure; a fair rating indicates the design speed would have a moderate or neutral influence; and a poor rating indicates the design speed would have a negative influence. The ratings for each measure were then considered to identify an overall rating for each alternative and to compare the alternatives to each other.

Exhibit 3. 65 mph Local Tunnel Alternatives





Because the two alternatives are the same everywhere in the Corridor, except the two focus areas of Dowd Canyon and Floyd Hill through the Twin Tunnels, the alternatives were only evaluated against the performance measures in the two focus areas. In all other areas of the Corridor, both alternatives are designed to a 65 mph design speed, and would therefore have the same results for the performance measures.

2.2.1 What criteria were considered, and why were these criteria selected?

The criteria used for the alternatives evaluation were consistent with the PEIS purpose and need, core values, and previously developed agreements and commitments for the Corridor, as well as support design standards and other state and federal requirements. The I-70 Mountain Corridor CSS process develops core values for a project, then identifies critical success factors for the project relative to those core values. Alternatives evaluation criteria are then established to measure the performance of alternatives in meeting the critical success factors.

The following core values were identified for this project because design speed decisions have the potential to affect and support these values in the Corridor:

- Mobility
- Safety
- Environment

- Community
- Constructability

Critical success factors were identified relative to these core values. Design speed decisions must provide CDOT the ability to design highway improvements that can successfully address these factors. The critical success factors became the alternatives evaluation criteria, and comprise the following major categories:

- Mobility
- Compatibility with non-roadway elements of the PEIS Preferred Alternative
- Safety
- Environmental sensitivity
- Respect for community values
- Constructability (short-term)
- Ability to implement (long-term)

Individual performance measures were developed for each criterion to measure the performance of the design speed alternatives against the criteria. The following subsections describe the alternatives evaluation criteria and associated performance measures and explain how they relate to design speed decision-making.

2.2.2 Mobility

2.2.2.1 How does design speed affect mobility?

As previously defined, design speed is one of the controlling criteria used by engineers to design roadways. Travel speeds affect travel times in free flow conditions but not in congested conditions. Consistency and homogeneity in the traffic flow improves travel reliability and predictability, which can also have a beneficial effect on travel times. Much of the length of the Corridor has posted speeds at or above 65 mph. Posted speeds are lower where there are geometric constraints. Actual or prevailing traffic speeds are often different than the design speed or posted speed and are more relevant and of interest to highway users. Since prevailing speed is easy to quantify, it is often used directly and indirectly as a measure of mobility. However, context is everything. Driver perceptions, geometric constraints, and Corridor conditions all influence Corridor speeds.

2.2.2.2 What mobility criteria were evaluated?

According the PEIS, the purpose for transportation improvements in the Corridor is to increase capacity, improve accessibility and mobility, and decrease congestion. For consistency with this previous evaluation, the same three mobility criterion used in the PEIS are included in this study. The increased capacity criterion is measured by the number of person trips in the peak and off-peak periods. To assess the improvement in mobility and accessibility the performance measure rankings are based on the travel time during peak and off-peak periods. Annual hours of congestion serves as the metric for determining the decrease in congestion. Since each of these measures are readily available from the PEIS, no new data were collected nor were new traffic forecasts prepared for this study.

2.2.3 Safety

2.2.3.1 How does design speed affect safety?

Roadway elements vary depending on the selected design speed, which has a corresponding effect on the speeds that drivers feel comfortable traveling on the roadway, as described in Section 1.3.2. From a safety perspective, an appropriate speed limit is an essential element of highway safety and the avoidance of crashes and mitigation of crash outcomes is the most important reason for imposing speed limits. An appropriate speed limit is safe, considered reasonable by most drivers, fair in the context of traffic law, and enforceable with available resources. Motorists tend to comply voluntarily with speed limits that are appropriate. Speed limits not considered reasonable typically result in greater speed differentials among motorists, as some comply with the regulation and others drive at the speed they consider appropriate for the conditions.

Although speed contributes to the occurrence and severity of crashes, the range in speeds is thought to contribute more to crashes than speed itself. Irrespective of the average speed on the highway, a greater deviation from average traffic speeds increases crash probability and the risk of a severe crash. Initial research into setting speed limits indicated that crash risk increased rapidly for motorists traveling two standard deviations or more above or below the mean operating speed (FHWA, 2012a). Thus, a smaller speed differential promoted by a reasonable speed limit can enhance safety and reduce the frequency and severity of crashes.

The most common methodology used to set speed limits is the 85th-percentile speed. The mean speed plus one standard deviation approximates the 85th-percentile speed for a normally distributed sample of speeds. Traveling at or around one standard deviation above the mean operating speed (which is approximately the 85th-percentile speed) has been correlated with the lowest crash risk for drivers (FHWA, 2012a). Therefore, the 85th-percentile speed is thought to separate acceptable speed behavior from unsafe speed behavior that disproportionately contributes to crash risk. The *Manual on Uniform Traffic Control Devices for Streets and Highways* (FHWA, 2009) indicates that posted speeds "should be within 5 mph of the 85th-percentile speed of free-flowing traffic."

Thus, design speed can influence traffic safety through provision of design elements such as horizontal and vertical curvature, lane widths, grades, and sight distance that support the 85th-percentile speed and the speed range that most drivers will operate within for a given set of roadway, weather, and volume conditions.

2.2.3.2 What safety performance measures were evaluated?

The two safety performance measures are related primarily to speed differential because research concludes that high speed differentials create safety concerns relative to frequency and severity of crashes. Extenuating circumstances such as adverse weather and congestion may exacerbate issues related to speed differential in the traffic stream. The two performance measures are described as follows:

- **Potential speed differential between cars and trucks on steep up and down grades.** Performance measure rankings are based on the potential speed differential between passenger cars and heavy trucks. The operating performance of heavy trucks decreases as vertical grade increases, resulting in a lower operating speed uphill. Truck drivers operate at lower speeds downhill to maintain control of their vehicles. On the contrary, passenger car performance is generally not impacted by up and down grades, and minimal change in operating speed results. The operating speed differential between passenger cars and heavy trucks is a potential safety issue. The 2011 AASHTO *A Policy on Geometric Design of Highways and Streets* states: "…the truck crash involvement rate increases significantly when the truck speed reduction exceeds 10 mph…On the basis of these relationships, it is recommended that a 10 mph reduction criterion be used as the general guide for determining critical lengths of grade." Figure 3-27 in *A Policy on Geometric Design of Highways and Streets* shows a graph of truck crash involvement rates. The rate for a 10 mph reduction is approximately 4 times greater than for no speed differential and the rate for a 20 mph reduction is approximately 4 times greater than the rate for a 10 mph reduction.

  Therefore, a 10 mph differential represents the interval for the rankings. The rankings are:

  - Good: < 10 mph speed differential
  - Fair: 10 mph to 20 mph speed differential
  - Poor: > 20 mph speed differential

- **Potential speed differential among vehicles during inclement conditions or congested periods.** Performance measure rankings are based on the potential speed differential among vehicles in the traffic stream during inclement conditions when the roadway surface is wet/icy or during congested periods when the volume demand approaches the roadway capacity. During these types of situations, most drivers will reduce their operating speed to a level that is comfortable for them to maintain control of their vehicle. This comfort level varies by driver and, therefore, a wider range of operating speeds occurs within the traffic stream than would typically occur during free-flow conditions on a dry roadway surface. The operating speeds shown in the Corridor crash data suggest most drivers are lowering their speeds during these types of conditions because a majority of the crashes occur at a speed below the posted speed limit.

The rankings are:

- Good: Posted speed is low enough that a minimal difference in operating speed compared to posted speed is necessary to obtain driver comfort level
- Fair: Narrower speed range between posted speed and operating speed per driver comfort level
- Poor: Wider speed range between posted speed and operating speed per driver comfort level

2.2.4 Compatibility with PEIS Preferred Alternative components

The PEIS Preferred Alternative consists of three major components: non-infrastructure improvements, AGS, and highway improvements. Design speed decisions on highway improvements must allow for implementation of the non-infrastructure improvements and AGS. Therefore, this criterion was developed to ensure compatibility between highway design speed decisions and other PEIS Preferred Alternative components. Performance measures were developed to evaluate how the design speed alternatives would affect the non-infrastructure improvements and AGS.

2.2.4.1 How does roadway design speed affect the AGS?

The AGS was included in the PEIS Preferred Alternative to meet needs for capacity and transit connectivity. CDOT's subsequent AGS Feasibility Study determined an alignment for the AGS. In parts of the Corridor, the proposed AGS alignment does not follow the existing I-70 alignment. In other parts of the Corridor, including the two focus areas of Dowd Canyon and Floyd Hill through the Twin Tunnels, the proposed AGS alignment is located next to I-70, in the I-70 median, adjacent to a proposed tunnel, or crosses over I-70. Because roadway design speed will affect the physical geometry and location of the roadway, design speed alternatives may affect the AGS alignment in locations where it interacts with the roadway.

The proposed AGS alignment was superimposed on the highway design in the focus areas for the 55 mph and 65 mph alternatives to examine how the design speed alternatives would interact with the AGS. A qualitative assessment resulted in the assignment of good, fair, or poor ratings for each design alternative in each focus area.

2.2.4.2 How does roadway design speed affect non-infrastructure components?

A wide variety of non-infrastructure components were included in the PEIS Preferred Alternative, such as bus, van, or shuttle service in mixed traffic, use of technology advancements to increase mobility, and traveler information and other intelligent transportation systems (ITS). Design speed generally does not affect CDOT's ability to implement non-infrastructure strategies, but this performance measure documented the interaction between design speed and non-infrastructure components. A qualitative assessment resulted in the assignment of good, fair, or poor ratings for each design alternative in each focus area.

2.2.5 Environmental Sensitivity

2.2.5.1 How does design speed affect environmental resources?

Roadway design speed affects the physical geometry and location of the roadway and construction activities. Both the physical roadway footprint and the construction methods and duration result in impacts on environmental resources. The 55 mph alternative tends to stay along the existing highway alignment, with flattened curves, and requires less complex construction activities over a shorter duration. The 65 mph alternative requires tunnels to accommodate the higher speeds, which results in different types of impacts than staying at grade on the existing highway alignment, and more complex construction for a longer period of time.

2.2.5.2 What environmental performance measures were evaluated?

Impacts on the following environmental resources present in the Dowd Canyon and Floyd Hill through the Twin Tunnels focus areas were evaluated: sensitive species and other wildlife habitat, wildlife crossings (linkage interference zones), paleontological resources, wetlands and waters of the U.S., gold medal fisheries, and geological hazards.

The proposed 55 mph and 65 mph alignments from the PEIS were superimposed on the PEIS environmental resource maps in the focus areas to examine how the design speed alternatives would impact resources. The refinements listed in Section 2.1.3 of this document, regarding emergency bypass routes and interchange accesses, were also considered. A qualitative assessment resulted in the assignment of good, fair, or poor ratings for each design alternative in each focus area.

2.2.6 Community Values

2.2.6.1 How does design speed affect community values?

Similar to environmental resources, the roadway design speed affects both the physical geometry and location of the roadway and construction methods and durations, resulting in the potential for impacts on community resources.

2.2.6.2 What community values performance measures were evaluated?

Impacts on the following environmental resources present in the Dowd Canyon and Floyd Hill through the Twin Tunnels focus areas were evaluated: historic resources, recreation resources, visual resources, and construction related impacts (air and noise emissions, traffic).

The proposed 55 mph and 65 mph alignments from the PEIS were superimposed on the PEIS community resource maps in the focus areas to examine how the design speed alternatives would impact resources. The refinements listed in Section 2.1.3 of this document, regarding emergency bypass routes and interchange accesses, were also considered. A qualitative assessment resulted in the assignment of good, fair, or poor ratings for each design alternative in each focus area.

2.2.7 Constructability

2.2.7.1 How does design speed affect constructability?

In some cases, the design speed can have impacts on the constructability of a project in the short term if the alternative introduces elements that are difficult to construct, such as a tunnel or large rock cuts or retaining walls in areas with steep slopes. Projects that involve changes to a curve on the existing alignment can introduce a complexity during construction to maintain traffic while the project is under construction. This often leads to detour routes that have additional impacts, or to longer construction schedules.

2.2.7.2 What constructability performance measures were evaluated?

Constructability of a project in the short term was evaluated by comparing the alternatives to a standard typical roadway project in regards to the complexity of the sequencing of construction, the duration of construction, or if the project includes elements that are difficult to construct.

2.2.8 Implementation

2.2.8.1 How does design speed affect implementation?

Complex engineering solutions required to balance the unique topography in the Corridor often come at a cost in the long term. Because roadway design speed will affect the physical geometry and location of the roadway, design speed alternatives will affect the long-term activities and costs of operating and maintaining the roadway. For example, large rock cuts in areas prone to slides or other geologic hazards require more maintenance than a roadway segment without those features. Tunnels are costly to operate and maintain and may require maintenance of additional roadway infrastructure for bypass routes. Design speed alternatives with more of these elements will be more difficult to implement and maintain.

2.2.8.2 What implementation performance measures were evaluated?

Complexity and technical feasibility of engineering solutions; maintenance costs Implementation Criteria evaluated include the structural complexity of the design (bridges, rock cuts, retaining walls, and tunnels); the long-term cost of operating and/or maintaining these large structures; and the amount of roadway infrastructure to be maintained.

Evaluation

3.1 How did the alternatives rate overall?

The performance of the design speed alternatives against the various criteria were summed into an overall rating for each alternative in each focus area. **Exhibits 4 and 5** illustrate the considerations and constraints in the Dowd Canyon and Floyd Hill through the Twin Tunnels areas, respectively. Appendix C contains a map book that illustrates all of the roadway improvements, including these focus areas. A more detailed discussion of each of the evaluation criteria follows.

The 55 mph alternative was rated higher than the 65 mph alternative in both Dowd Canyon and Floyd Hill through the Twin Tunnels areas.

In the Dowd Canyon focus area, the 55 mph alternative was rated as “Fair Plus” and the 65 mph alternative was rated as “Fair Minus.” Both alternatives would be complex and have the potential for numerous impacts during construction and operation. However, the 55 mph alternative would be easier and less expensive to implement, and would have a shorter construction duration, because it would not require tunnel construction. Additionally, the 65 mph alternative would likely result in more impacts to community resources due to changes in access, longer duration of construction, and effects of staging areas, haul roads, and the new alignment on nearby private properties and local travelers. Impacts on adjacent environmental resources like sensitive species habitat and wetland could be greater under the 55 mph hour alternative because it would expand the roadway footprint throughout the entirety of the existing alignment, interacting with adjacent sensitive resources. However, because the constraints are better understood, design modifications may be possible to avoid or minimize those impacts with the 55 mph alternative, as these impacts and the engineering options to avoid impacts are more widely understood and employed than with tunnel construction under the 65 mph alternative.

In the Floyd Hill through the Twin Tunnels focus area, the 55 mph alternative was rated as “Fair” and the 65 mph alternative was rated as “Poor.” As in Dowd Canyon, both alternatives would be complex and have the potential for numerous impacts during construction and operation. However, because of the length of the tunnels required, the 65 mph alternative would be much more difficult to construct, finance, and maintain. Additionally, the curve modifications required on the existing I-70 roadway would require substantial rock cuts, which would also introduce greater complexity and cost of construction and maintenance. The impacts and costs of the 65 mph alternative during construction and operation would be substantially higher than those of the 55 mph alternative.

3.2 How does the design speed decision affect mobility?

Mobility measures of effectiveness evaluated for the build alternatives in the PEIS improve over the no build alternative because of the added roadway capacity but are the same between 55 and 65 mph alternatives. This suggests that the additional capacity provided by the new travel lanes and auxiliary lanes is responsible for the increase in mobility not whether the posted Corridor speed is 65 mph versus 55 mph.

Exhibit 4. Dowd Canyon MP 170 to MP 173

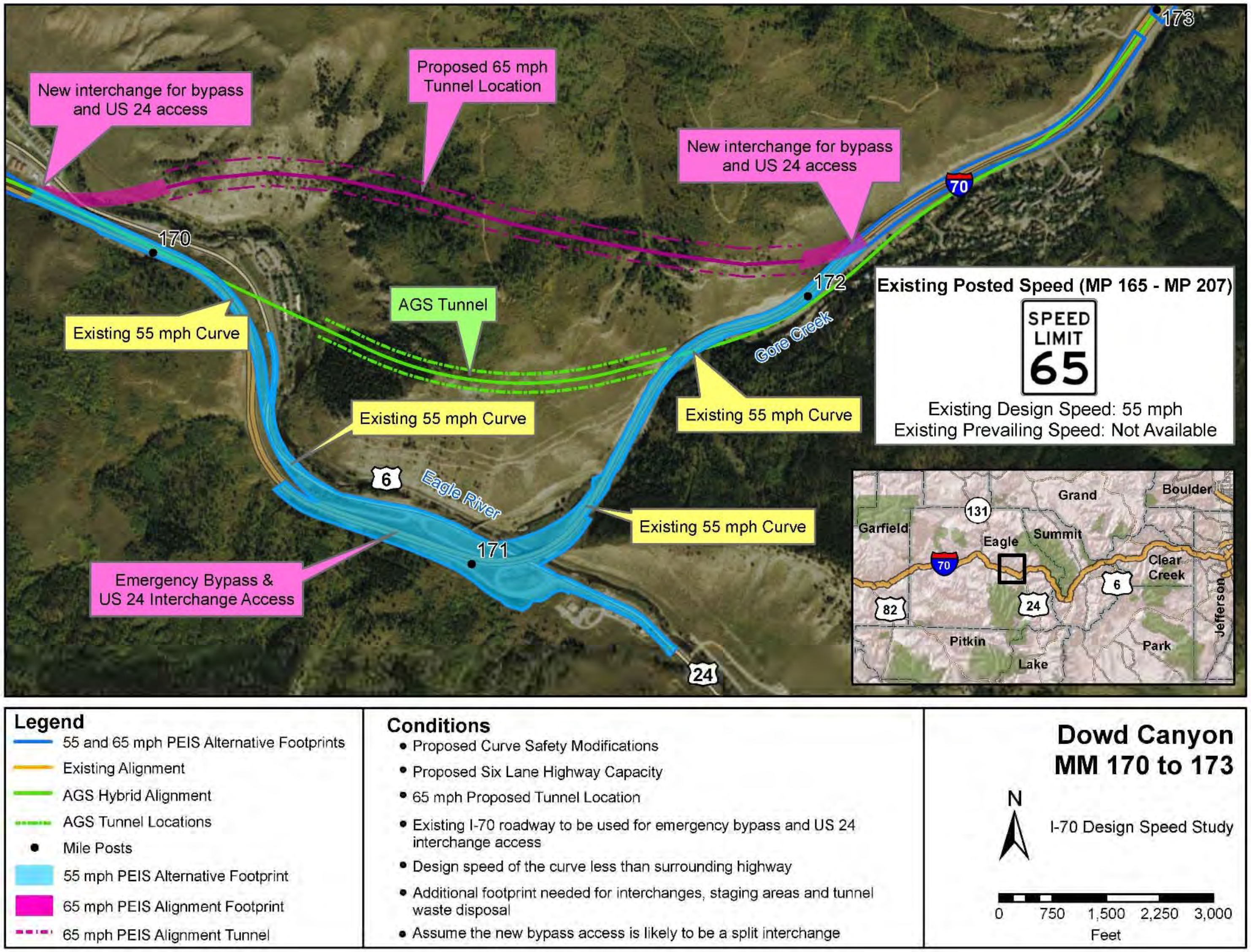
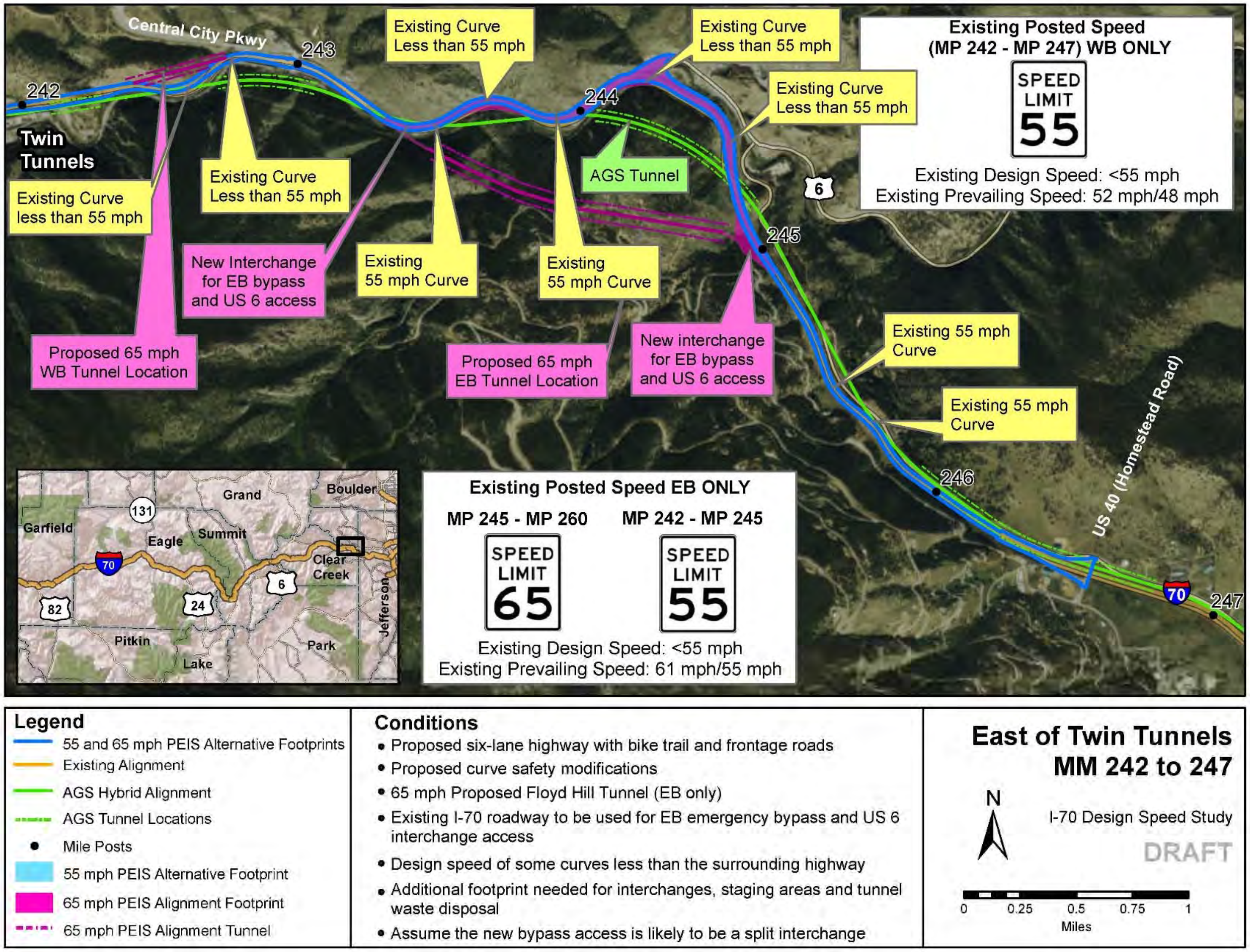


Exhibit 5. Floyd Hill through the Twin Tunnels MP 242 to MP 247



There is an increase in the number of person trips served within the Corridor under both the 55 and 65 mph alternatives and no measurable difference between the two alternatives according to the PEIS. Similarly, travel times for both the 55 and 65 mph alternatives improve over the no build condition but neither alternative has a measurable difference between Corridor travel times in either the peak or off-peak. Annual hours of congestion within the Corridor are reduced under both 55 and 65 mph alternatives but there is no measurable difference between the two alternatives.

These measures are good indicators of Corridor-wide mobility but are also applicable to the focus areas of improvements. For example, the travel time difference between the 55 and 65 mph alternatives at Dowd Canyon is negligible because the length of the improvement is short while the length of the trips are long. Furthermore, it is uncertain if a 65 mph speed could be achieved in this area because similar tunnels in the Corridor are operated at reduced speed limits both within and approaching the tunnels. This same conclusion can be drawn in the Floyd Hill through the Twin Tunnels area for the same reasons.

3.3 How does the design speed decision affect safety?

The evaluation is not applicable for the identified performance measures and, therefore, inconclusive from a safety perspective at the Dowd Canyon location. The evaluation results suggest the 55 mph alternative is preferable to the 65 mph alternative at the Floyd Hill through the Twin Tunnels location.

Dowd Canyon: Neither of the performance measures are applicable, so the evaluation did not distinguish between alternatives in Dowd Canyon. As this particular area is not characterized by steep vertical grades (less than 4 percent), the performance measure relative to speed differential on steep grades is not applicable. Recorded speed data along this segment suggests a minimal operating speed differential between passenger vehicles and heavy trucks, further indicating this performance measure is not applicable at this location.

The unique variables associated with each alternative at this location do not permit a homogeneous comparison with regard to the second performance measure (speed differential during inclement weather or congested conditions). For the 55 mph alternative, the design speed for the curve safety modifications will be 55 mph although the existing posted speed limit of 65 mph will not likely be lowered, resulting in a persisting differential between the design and posted speeds that would not exist under the 65 mph alternative condition. For the 65 mph alternative, the speed limit inside the tunnels will likely be posted at 50 or 55 mph (even though the curves may support a 65 mph speed) to maintain consistency with the other tunnels in the Corridor. This would result in a posted speed differential between the tunnels and the adjacent roadway sections that would not exist with the 55 mph alternative condition.

Floyd Hill through the Twin Tunnels: Both alternatives received a poor evaluation result for the first safety performance measure. The steep grade at Floyd Hill potentially results in a speed differential between trucks and cars that is greater than 20 mph under both design speeds. Research studies show that maximum truck operating speed is approximately 25 mph on uphill grades of 6 percent or more; braking on downhill grades also requires trucks to operate at lower speeds. Passenger vehicles traveling at a posted speed of either 55 or 65 mph would result in a speed differential greater than 25 mph. Recorded speed data along this segment shows that this speed differential does occur under existing conditions. Although reducing the grades is not proposed at Floyd Hill, both alternatives add another lane that would provide the ability to separate slower moving vehicles from the mainstream.

The evaluation results for the safety performance measure for speed differential during inclement or congested conditions vary by alternative. The 55 mph alternative received a fair rating because of the potential for a narrower speed range between the posted speed and the resultant operating speed than could be expected with the 65 mph alternative. A smaller difference between these two speeds improves driver comfort level and encourages a more consistent traffic flow in inclement conditions or congested periods. A lower posted speed can reduce the tendency for drivers to travel too fast for conditions and more closely match their operating speeds to the prevailing conditions. Conversely, the 65 mph alternative received a poor rating because of the potential for a wider range between operating and posted speed than could be experienced with the 55 mph alternative. The greater speed differential between drivers operating at/near the posted speed and those operating at a more appropriate speed for the conditions introduces turbulence in the traffic stream and driver behavior.

3.4 How does the design speed decision affect compatibility with PEIS Preferred Alternative non-roadway elements?

Both design speed alternatives would have the same level of compatibility with the AGS and non-infrastructure components of the PEIS Preferred Alternative.

3.4.1 Compatibility with AGS Component

In both focus areas, the proposed AGS alignment is located in the median of I-70, crosses over I-70, or is in a tunnel near the existing I-70 roadway and adjacent to the 65 mph alternative tunnel. Potential conflicts between highway and AGS improvements exist in both focus areas, and the differences in physical geometry between the 55 mph and 65 mph alternatives would result in different interactions between highway and AGS improvements. For example, AGS and 65 mph highway tunnels would need to be planned for compatibility, but this type of tunnel coordination would not be needed with the 55 mph alternative. However, highway and AGS improvements would be constructed at different times and could be planned to be compatible with each other, regardless of design speed and highway configuration. Therefore both design speed alternatives were found to have the same level of compatibility with the AGS component of the PEIS Preferred Alternative in both focus areas. The overall rating for both alternatives this performance measure is “fair” because potential conflicts between highway and AGS design do exist, but these conflicts could be resolved during planning and design.

3.4.2 Compatibility with non-infrastructure component

Non-infrastructure improvements identified in the PEIS can be implemented in conjunction with either of the design speed alternatives because they are not dependent on the physical configuration of the roadway. Therefore both design alternatives would have the same level of compatibility with non-infrastructure improvements. The rating for both alternatives for this performance measure is “good” because all of the non-infrastructure strategies identified in the PEIS could be implemented with either alternative.

3.5 How does the design speed decision affect environmental sensitivity?

Both design speed alternatives have the potential for substantial impacts on environmental resources, particularly on geological and paleontological resources, wildlife, and wetlands and waters of the U.S. However, impact types and locations would differ.

In both focus areas, geological and paleontological resources would be affected by rock cuts along the at-grade roadway for the 55 mph alternative and by rock cuts and tunnel boring for the 65 mph alternative. Particularly for the 55 mph alternative, rockfall and landslide hazards in Dowd Canyon and rockfall and debris flow hazards in the Floyd Hill through the Twin Tunnels focus area could be worsened due to the large cuts needed to accommodate the wider road. The 65 mph alternative would have greater potential for impacts to paleontological resources due to tunnel boring, and tunnel construction activities in both focus areas could be complicated by the potential for rockfall, landslides (in Dowd

Canyon), and debris flow (at Floyd Hill through the Twin Tunnels) during construction. Tunnel waste would need to be hauled away and disposed, creating additional environmental impacts.

In both focus areas, 55 mph alternative roadway widening and curve flattening would result in impacts outside the highway right-of-way and could affect adjacent biological resources, including sensitive species habitat; the Eagle River, Gore Creek, and Clear Creek; the Gore Creek gold medal fishery; and wetlands. Wildlife linkage interference zones occur in both focus areas, and I-70 would remain a barrier to wildlife crossings. The 55 mph alternative would have greater potential for direct impacts to wetlands and waters of the U.S. due to the wider highway footprint immediately next to the Eagle River, Gore Creek, and Clear Creek.

Under the 65 mph alternative, impacts of roadway widening would be avoided due to the new tunnels in the focus areas; however, constructing the tunnels and split interchanges for access to nearby U.S. highways would result in larger disturbance areas at the tunnel entrances and exits. These disturbance areas would be in proximity to the Eagle River, Gore Creek, and Clear Creek. The tunnels would result in some reduction in the barrier to wildlife crossing because interstate traffic would move into the tunnel at Dowd Canyon and eastbound interstate traffic would move into the tunnel at Floyd Hill; however, the existing I-70 alignment would remain in operation as an access road in both focus areas and would continue to be a barrier to wildlife movement.

3.6 How does the design speed decision affect community values?

Construction of either design speed alternative would cause traffic disruption, associated disruption of business and property access and tourism activities, and dust, air, and noise emissions. In both focus areas, the 55 mph alternative construction duration would be shorter than the 65 mph alternative, resulting in a shorter period of disruption to communities. Although the 65 mph tunnel construction would take place outside of the existing highway footprint, disruption of traffic on I-70 would still occur due to staging, haul roads, and construction activities as well as interchange construction and, at Floyd Hill, westbound I-70 improvements.

Dowd Canyon permanent impacts: No business or residential relocations are anticipated under the 55 mph alternative. Potential impacts to trails, historic, and recreation sites would occur at the tunnel approaches and construction work areas. Impacts would be greater under the 65 mph alternative because staging and construction of the tunnels and split interchange could result in business and residential relocations as well as impacts to trails, historic, and recreation sites.

Floyd Hill through the Twin Tunnels permanent impacts: The 55 mph alternative has the potential for substantial impacts to recreational resources, including Section 4(f) properties, located adjacent to the existing I-70 alignment. Although a full cultural resources survey would need to be conducted, the 55 mph alternative would not impact any previously identified historic resources, and no residential or business relocations are anticipated. Expanding the highway could result in substantial visual effects due to large rock cuts, retaining walls, and the larger highway footprint in the narrow canyon.

The 65 mph alternative would impact recreational resources, including Section 4(f) properties, located adjacent to the existing I-70 alignment. Substantial impacts on historic resources would likely occur at the tunnel approaches. The tunnel would provide an opportunity for improved visual conditions due to the smaller at-grade roadway footprint.

3.7 How does the design speed decision affect constructability?

This criteria for constructability identified and analyzed the short-term impacts of a chosen project. The constructability of a specific project was evaluated based on two main elements: Elements that are difficult to construct, such as a tunnel or large rock cuts, and elements that require complex traffic management during construction, such as curve modifications on the existing alignment.

Tunnel construction is more specialized and complex than surface road construction, often encountering unforeseen geotechnical and other challenges. Bridges may be required at the tunnel entrances, and blasting activities would be adjacent to nearby residential properties. Tunnel waste material (more than 500,000 cubic yards at Dowd Canyon and upwards of 5 million cubic yards at Floyd Hill) would need to be trucked elsewhere, and access roads and staging areas would need to be constructed at the tunnel approaches. Due to complexity of tunnel construction, overall construction duration would be extended; however, much of the tunnel can be constructed offline before traffic is permanently moved. Costs for tunnel construction are considerably higher than standard roadway construction.

Complicated phasing, lack of detour routes, and long construction schedule to maintain existing highway capacity during construction lead to lower constructability ratings. Rock cuts and blasting near slopes may require additional closures to protect the traveling public and construct under live traffic.

3.8 How does the design speed decision affect the ability to implement roadway improvements?

Opposite to the Constructability criteria, the ability to implement criteria identified and analyzed the long-term impacts of a chosen project. Complex engineering solutions require continued maintenance and operational costs beyond what is typically required for a standard roadway.

At Dowd Canyon, both alternatives introduce complexities in engineering design and solutions due to the physical constraints of the topography. There is an existing frontage road intertwined with the interstate. Walls or rock cuts could be required to avoid impacts to the Eagle River and Gore Creek. Assuming that the existing I-70 would need to remain in place to provide access to US 24 and an emergency detour route for tunnel closures, the alternative adds miles to highway maintenance and introduces new infrastructure in tunnels and interchanges, increasing operations and maintenance costs.

At Floyd Hill through the Twin Tunnels, the 65 mph alternative includes two tunnels: a tunnel for eastbound traffic plus surface roadway for westbound traffic at Floyd Hill and a tunnel for westbound traffic plus surface roadway for eastbound traffic at Hidden Valley. The Floyd Hill tunnel is more than 2 miles long—longer than the Eisenhower-Johnson Memorial Tunnels—and curve modifications on surface roadway would require substantial rock cuts (thousands of feet) to accommodate 65 mph template.

For constructability, this alternative would require the construction of *each* tunnel first, and then the roadway, so traffic can travel through the tunnel while the roadway construction occurs. This would be a very long construction process.

While the 55 mph alternatives include substantial wall and rock cut costs, the 65 mph alternative introduces costs for tunnels, as well as for a new interchange with US 24 and US 6. Therefore, the costs are much higher for the 65 mph alternative.

Conclusion

4.1 What is the recommendation?

For the PEIS Preferred Alternative maximum program of improvements, this study recommends a Corridor design speed of 65 mph with the exception of the Dowd Canyon and Floyd Hill through the Twin Tunnels focus areas, which are recommended to have a lower design speed. The 65 mph alternative offers no mobility benefits over the 55 mph alternative, is less desirable from a safety perspective at Floyd Hill because of the already challenging speed differentials that are exacerbated by higher speeds, and would be more expensive and impactful to construct and maintain.

A 65 mph Corridor design speed is recommended except in Dowd Canyon and Floyd Hill through the Twin Tunnels areas.

A 65 mph design speed is recommended in all Corridor locations outside of the two focus areas, because both alternatives have alignments that support a 65 mph design speed except in the focus areas. In the focus areas, a lower design speed is recommended. The 65 mph alternative has more environmental and constructability impacts and costs due to the physical constraints in Dowd Canyon and Floyd Hill through the Twin Tunnels areas. Additionally, the 65 mph alternative offers no mobility benefit (because these isolated locations of lower travel speeds have very little effect on corridor travel times and no effect on capacity) and presents fewer or similar safety benefits than the 55 mph alternative. Although this study analyzed a 55 mph design speed in the focus areas, the study's recommendation allows the design speed in these areas to be different than 55 mph, depending on the existing geography and topography. In some instances, it may be feasible to design a curve to 60 mph because the road bench is wide enough, while in others, it may not be feasible to reach even 55 mph if the roadway is physically constrained. In the focus areas, Tier 2 projects should maximize design speed while considering the tradeoffs between higher design speed and impacts. For example, if a 60 mph curve can be obtained without resulting in substantial rock cuts or creek encroachment, that design should be pursued. But if a 60 mph or even 55 mph curve would cause substantial rock cuts or creek encroachment, then a lower design speed that can be more feasibly constructed should be considered.

4.2 What are the next steps?

Tier 2 projects no longer need to consider both a 55 mph and 65 mph design speed when designing roadway improvements. This study's recommendation allows future projects to do the following:

- Design projects in the focus areas of Dowd Canyon and Floyd Hill through the Twin Tunnels to a design speed that is lower than 65 mph and that maximizes design speed while considering the tradeoffs between design speed and impacts
- Design roadway improvements with a 65 mph design speed in all other Corridor locations

The following sections discuss traffic mitigations and enhancements that should be considered for future Tier 2 projects.

4.3 What mobility mitigation and enhancements should be considered for future Tier 2 roadway improvements?

Future Tier 2 project teams will be challenged to design both physical and operational alternatives that increase mobility, enhance safety, and meet design standards while minimizing social and environmental impacts. Within the context of the Corridor having significant existing and future congestion, limited opportunities to expand capacity, and known engineering constraints, these project teams will be faced with design decisions that will require creativity and compromise as they embark on this delicate balance.

Strategies that may be considered by project teams to mitigate impacts of design decisions, enhance mobility, or address known recurring or non-recurring congestion shall be included in a Corridor and/or regional ITS infrastructure plan, shall be compatible with regional mobility goals, and shall meet the department's operational objectives.

In addition to strategies already in place or being considered by CDOT's Division of Transportation Systems Management & Operations division such as the I-70 Peak Period Shoulder Lanes and the Heavy Tow and Courtesy Patrol programs, project teams shall look for innovative ways to mitigate design decisions and enhance mobility. This may include traditional travel demand management strategies such as enhanced travel information or incident management, existing ITS elements such as variable message signs, as well as emerging Active Traffic Management strategies such as dynamic lane assignment, junction control, and variable speed limits (VSL). In conjunction with this study, CDOT prepared a *Guide to Variable Speed Limits on the I-70 Mountain Corridor* (CDOT, 2015b) that includes specific suggestions that could be applied to the Corridor between Vail and Golden (MP 172 and MP 262) for VSL operations based on weather, incidents, construction zones, congestion, and managed lanes. As CDOT's VSL practices and policies continue to advance, VSL will become an increasingly important tool for improving safety and mobility in the Corridor in both operating the Corridor and implementing Tier 2 improvements.

Each of these considerations have the potential to improve mobility by changing demand, reducing turbulence in the traffic stream thereby delaying or preventing flow breakdown, and detecting and reacting to incidents. Incorporating these mitigation measures and enhancement strategies into the Tier 2 projects will help CDOT to meet their Strategic Policy Initiative of reducing congestion, improving system reliability, and improving the freight network and economic vitality for this important freeway Corridor of statewide importance.

4.4 What safety mitigation and enhancements should be considered for future Tier 2 roadway improvements?

From a safety perspective, it is assumed that the design of future roadway improvements will incorporate "nominal" safety elements by adhering to design standards such as lane width, shoulder width, sight distance, horizontal and vertical curvature, superelevation, breakaway devices on roadside objects such as light poles and sign posts, curve delineation such as warning/advisory speed signs, and retroreflective materials for signs/markings/ delineators/barriers. "Substantive" safety elements that address specific safety issues at spot locations should be considered during the project design process per the discussion in this subsection. Project teams should analyze the most recently available crash data to identify crash issues and then review the latest industry publications and practices to identify effective mitigation measures. These measures should be incorporated into the roadway improvement designs per the current Manual on Uniform Traffic Control Devices and CDOT Standards guidance.

The Level of Service of Safety (LOSS) concept should be followed while analyzing crash data and identifying mitigation measures. This concept was first developed by CDOT and has been identified by

FHWA as a "Noteworthy Practice" for Highway Safety Improvement Programs. The LOSS concept quantifies the safety problem by determining how the roadway segment is performing with regard to its expected crash frequency and severity at a given annual average daily traffic value. The number of deviations from the norm (expected crash frequency and severity) represents specific levels of safety as follows:

- LOSS-I - Indicates low potential for crash reduction;
- LOSS-II - Indicates low to moderate potential for crash reduction;
- LOSS-III - Indicates moderate to high potential for crash reduction; and
- LOSS-IV - Indicates high potential for crash reduction.

LOSS I and II would not be ideal locations to invest in substantive mitigation measures due to the limited potential impact on safety. That is, not as many crashes could be prevented or severity reduced by implementing mitigation measures at these locations. This could lead to a low benefit-to-cost ratio. There is potential to reduce the frequency and severity of crashes at LOSS III locations with the implementation of targeted, low-to-moderate cost mitigation measures. The greatest potential to improve safety is at the LOSS IV locations. With higher numbers of crashes and higher severity of crashes at these locations, the greater potential for societal costs savings justifies more costly mitigation measures. Exact mitigation measures at specific locations would be dependent upon crash history and operating conditions.

Some of the higher cost mitigation measures such as median barrier and those that require a fiber optic connection would be most effective with continuous installation for several miles per location or the entire Corridor. The common crash types have historically occurred along the length of the Corridor and not at a few isolated locations. Since compromised roadway surface and congestion conditions can occur for several miles and at several locations simultaneously along the Corridor, better driver guidance would be provided if the mitigation measures are installed along the length of the Corridor, or at a minimum for a few contiguous miles in multiple locations.

The following lists potential mitigation measures for the crash types identified during the conduct of this study.

LOSS III: Low to medium cost mitigation measures by crash type:

Lane departure crashes

- Continuous median barrier
- Shoulder and edge line rumble strips
- Skid-resistant pavement surfaces at curves and steep downgrades
- Static curve warning signs with enhanced conspicuity such as flashing beacon on top of sign or flashing LED lights along the outline of the chevron or arrow
- Pavement safety edge
- Snowplowable raised pavement markers

Roadway surface condition crashes

- Seasonal static warning signs with enhanced conspicuity such as flashing beacon on top that indicate icy/wet/slippery surface conditions
- Skid-resistant pavement surfaces at curves and steep downgrades
- Pavement grooves cut in longitudinal direction at curves

- Enforcement of slower operating speeds appropriate for the conditions
- Rolling speed harmonization using state patrol / local sheriff & police forces
- Public education campaigns

Congestion/rear-end crashes

- Enforcement of slower operating speeds appropriate for the conditions
- Rolling speed harmonization using state patrol / local sheriff & police forces
- Public education campaigns

LOSS IV: LOSS III measures plus High cost mitigation measures by crash type:

Lane departure crashes

- Relocate objects outside the clear zone
- Modify side slopes to improve potential for driver to recover from lane departure
- Install fiber optic network that supports
  - Dynamic curve warning systems
  - Radar speed feedback signs

Roadway surface condition crashes

- Install fiber optic network that supports
  - VSL signs
  - Radar speed feedback signs
  - Dynamic condition signs that indicate icy/wet/slippery surface conditions
- Automated anti-icing systems at curves

Congestion/rear-end crashes

- Install fiber optic network that supports
  - VSL signs
  - Radar speed feedback signs
  - Queue warning systems

4.5 What geometric design mitigation and enhancements should be considered for future Tier 2 roadway improvements?

A design exception to FHWA's 13 controlling criteria is considered when a design outside the normal range of practice is necessary. According to *Mitigation Strategies for Design Exceptions* (FHWA, 2007a): *A design exception is a documented decision to design a highway element or a segment of highway to design criteria that do not meet minimum values or ranges established for that highway or project*. In 2007, FHWA published the *Mitigation Strategies for Design Exceptions*, a technical report which, in part, provides potential mitigation strategies for these design exceptions. Several of the mitigating strategies are already employed by CDOT, as standard elements of design, including p shoulders, signing, intersection lighting, and traversable side slopes.

Every project in the Corridor is unique and requires individual consideration when considering mitigation techniques. **Table 1** lists some of the recommended mitigation strategies that should be considered by designers in the Corridor. Some mitigation strategies are widely used and well documented as to their effectiveness, while other new and innovative ideas are being implemented and tested each day. Designers should consult the most recent research available to assess the effectiveness of existing and emerging strategies.

Table 1. Design Speed Considerations
Roadway Design

Controlling Criteria	Mitigation Strategy	Purpose
Lane/Shoulder Width	Signing	Optimize Safety and operations by distributing available cross–section width Provide advance warning of lane width reduction Improve ability to stay within the lane
	Pavement markings (width, recessed, raised)	
	Delineators	
	Lighting	
	Rumble strips (centerline, shoulder, edge)	
	Paved shoulders	Improve ability to recover if driver leaves the lane
	Safety edge	
	Provide pulloff areas	Provide space for enforcement and disabled vehicles
Bridge Width	High visibility bridge rail	Improve visibility of narrow bridge, bridge rail, and lane lines
	Signing	
	Bridge lighting	
	Skid-resistant pavement	Maintain pavement on bridge that will provide safe driving conditions
	Anti-icing systems	
Horizontal Alignment	Dynamic curve warning systems	Provide advance warning
Cross Slope	Transverse pavement grooving (Portland Cement Concrete pavement)	Improve drainage
	Open-graded friction courses (hot mix asphalt pavement).	
	Pavement edge drains	
	Adjusting gutter profile on curbed cross sections	

4.6 How does this recommendation guide alternatives analysis for future Tier 2 processes?

This design speed evaluation completes the requirement in the I-70 PEIS ROD to make a decision about design speeds Corridorwide. It determines that the design speed for Corridor improvements will be 65 mph, as outlined in the I-70 Mountain Corridor Design Guidelines (CDOT, 2009a), except in the two focus areas of Dowd Canyon and Floyd Hill through the Twin Tunnels where a 65 mph design speed offers no Corridorwide benefit but results in substantial additional impacts, costs, and complexity. For the Tier 2 projects in these focus areas where 65 mph is not recommended based on the evaluation conducted for this study, a 55 mph design speed is recommended; however, teams will have the flexibility to determine an appropriate design speed – lower or higher – based on current conditions, design guidelines, and evolving technology that may affect design or travel speeds.

CDOT will update the I-70 Mountain Corridor Design Guidelines (https://www.codot.gov/projects/contextsensitivesolutions/docs/aesthetics/engineering-design-criteria-and-illustration) to clarify and refine the design speed recommendation in this report. The process of updating the I-70 Mountain Corridor CSS tools is consistent with the CSS 6-step process that allows for continuous improvement and the adaptive management component of the PEIS Preferred Alterative implementation.

For all Tier 2 roadway improvement projects, project teams should consider and incorporate measures to mitigate issues with speed differentials to improve safety and mobility for Corridor travelers. In areas where roadway improvements are not proposed, this decision does not change CDOT's evaluation and setting of speed limits or recommend posted speeds for the Corridor, which are anticipated to remain variable.

This study fulfills the ROD commitment for a Tier 2 NEPA process to identify a design speed for corridor improvements. The signature below documents completion of the NEPA Tier 2 process outlined in the ROD. The design speed decision from this study fits NEPA Programmatic Categorical Exclusion category (c)(1) as a planning study that does not involve or lead directly to construction. No significant environmental impacts will result from this study.

4/22/16

Environmental Policy and Biological Resources Section Manager Signature | Date

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