5 DESIGN CRITERIA

One of the first challenges faced by the design team was developing appropriate and up-to-date design criteria for this project. This is an essential step, as it helps define many of the geometric elements of design according to current standards. Design standards are based on many factors, including type of roadway facility, functional classification, and desired speed. Chapter 6 will discuss in further detail how each of the studied alternatives and design variations meets current design standards, thereby increasing safety along the US 550 corridor.

The *US 550 Environmental Assessment and Finding of No Significant Impact (2005 US 550 EA and FONSI)* (CDOT; FHWA, 2005) provided clear guidance on design speed, number of lanes, lane width, and median width for the project. The *US 160 Environmental Impact Statement* (*2006 US 160 EIS*) (CDOT; FHWA, 2006) and the *Supplemental Final Environmental Impact Statement* (*2012 SFEIS*) (CDOT; FHWA, 2012) provided guidance on number of lanes, lane width, and median width, but were less clear about what the design speed should be on US 550. Many of the design criteria elements are based on design speed, so the first challenge the design team faced was to determine an appropriate design speed.

5.1 DESIGN SPEED

5.1.1 US 550

Project Site Description

As it enters Colorado from New Mexico at milepost (MP) 0, US 550 is a four-lane divided highway that follows the Animas River. The highway transitions to two lanes by MP 3. Approximately 4.5 miles north of the border, US 550 leaves the river valley and climbs 300 feet up Bondad Hill to the top of Florida Mesa. For the next 10 miles, US 550 remains on the top of the mesa in level to rolling terrain with flat curves and long sight distances. Just north of CR 220, US 550 begins the 200 vertical-foot descent down Farmington Hill to the junction with US 160. The current posted speed limit on US 550 is 60 mph south of CR 220, 45 mph through the CR 220 intersection, and 35 mph on Farmington Hill.

Design Speed Considerations

The *2005 US 550 EA and FONSI* and the *2006 US 160 EIS* propose upgrading the existing two-lane US 550 facility to four lanes from the New Mexico state line north approximately 16 miles to the junction with US 160. Design speed for the preferred alternative from the *US 550 EA and FONSI* is 70 mph south of CR 220, resulting in an expected posted speed limit of 65 mph for portions of the corridor approaching the project area being addressed in this study.

North of CR 220, the various alternatives considered in the *2012 SFEIS* and presented in the August 27, 2012, letter from the Webb Ranch have a wide range of design speeds—35 to 70 mph, depending on the alternative.

To determine the most appropriate design speed for the US 550 south connection, the design team issued a separate design speed memo (see **Appendix K**), which recommended that the US 550 design speeds fall within the ranges shown in **Table 5-1**. The memo took into consideration key factors used in determining design speed, including functional classification, anticipated operating speed, desired speed limit and speed reduction zones, terrain, and corridor consistency.

Table 5-1: US 550 Design Speed

Location	Desirable Minimum Design Speed	Absolute Minimum Design Speed [1]
US 550 from New Mexico state line to CR 220 (adjacent to study area)	70 mph[2]	70 mph[2]
Southern curves near CR 220/MP 15.4	60 mph	55 mph
Northern curves near US 160	50 mph	40 mph

1 Minimum design speeds should only be considered if it is not possible to obtain the desirable design speed.
2 Actual per *US 550 EA*, except 65 mph at Bondad Hill per *US 550 Field Inspection Review (FIR) plans*

Based on these design speeds and classifications, the design team developed the remaining design criteria for US 550 and its interchange ramps, which are shown in **Table 5-2** and **Table 5-3**.

5.1.2 CR 220

The current posted speed limit on CR 220 is 35 mph (La Plata County classifies CR 220 as a Collector). All of the studied alignments will require reconfiguring a short portion of CR 220 to connect into US 550. Even though all westbound traffic is coming to a stop at that interchange, it could be made safer through design enhancements that would improve CR 220 sight distance and curvature approaching the US 550 intersection. To accomplish this, a design speed of 45 mph was selected for CR 220. Because CR 220 operates essentially as a T-intersection, with only local and Eagle Block business traffic continuing to the west of US 550, the American Association of State Highway and Transportation Officials (AASHTO) Low Speed Urban criteria was used to set the curve radius and superelevation. Recommended design criteria for CR 220 can be found in **Table 5-2**.

5.2 Functional Classification

The main function of US 550 in the Four Corners region is mobility. Most travelers are traveling significant distances between urban centers. The roadway also serves as the only north-south truck route in the region.

According to the AASHTO *Policy on Geometric Design of Highways and Streets* (AASHTO, 2004), US 550 should be classified as a Rural Principal Arterial, as it is suitable for interstate travel, movement between urban centers, and integrated movement. The CDOT Straight Line Diagram lists the functional classification for US 550 as a Principal Arterial. Based on this functional classification and on other characteristics of the highway, the Colorado State Highway Access Code access category for US 550 is R-A (Rural Regional Highway): *This category is appropriate for use on highways that have the capacity for medium to high speeds and relatively medium to high traffic volumes over medium and long distances in an efficient and safe manner. They provide for interregional, intra-regional, and intercity travel needs. Direct access service to abutting land is subordinate to providing service to through traffic movements. This category is normally assigned to National Highway System routes, significant regional routes in rural areas, and other routes of regional or state significance*.(CDOT, 1988, p. 37)

Table 5-2: US 550 and CR 220 Design Criteria

DESIGN PARAMETERS	PROJECT RECOMMENDATION		
	US 550		CR 220
	SOUTH CURVES	NORTH CURVES	
CLASSIFICATION	RURAL PRINCIPAL ARTERIAL		RURAL COLLECTOR
TERRAIN	ROLLING		ROLLING
DESIGN VEHICLE	WB-67		
AVERAGE DAILY TRAFFIC (2013)	7,900		1,400
AVERAGE DAILY TRAFFIC (2035)	21,600		9,000
DESIGN SPEED (MPH)	55	40	45
POSTED SPEED (MPH)	50	35	35
HORIZONTAL CURVES			
MINIMUM RADIUS	960	444	1039
MAXIMUM SUPERELEVATION	8%	8%	NORMAL CROWN
VERTICAL CURVES			
CREST (K)	114	44	61
SAG (K) (for Headlight Sight Distance)	115	64	79
MAX. GRADE DIFFERENCE REQUIRING NO CURVE	0.2%	0.2%	0.2%
STOPPING SIGHT DISTANCE (FT)	495	305	360
PASSING SIGHT DISTANCE (FT)	1985	1470	1625
GRADE			
MINIMUM	0.50%		0.50%
MAXIMUM	5%		8%
MAXIMUM AT INTERSECTION	5% w/in 100'		5% w/in 100'
PAVEMENT CROSS SLOPE	2%		2%
CROSS SECTIONAL ELEMENTS			
NUMBER OF THRU LANES	4		2
LANE WIDTH (FT)	12		12
SHOULDER WIDTH (FT)	10		4
MEDIAN WIDTH (FT)	46' S of CR 220 / 18' N of CR 220		0
CLEAR ZONE WIDTH (FT)	30		16
SIDE SLOPE DISTANCE "Z" (FT) (Where Applicable)	12		
SIDESLOPE (MAXIMUM)			
CUT	4:1 DES. / 3:1 MAX		4:1 DES. / 3:1 MAX
FILL	4:1 DES. / 3:1 MAX		4:1 DES. / 3:1 MAX
REDIRECT TAPERS	55:1	30:1	12:1

Table 5-3: US 550 Interchange Design Criteria

DESIGN PARAMETERS	PROJECT RECOMMENDATION
DESIGN VEHICLE	WB-67
ENTRANCE - EXIT RAMP SPACING	1600'
SIGNAL SPACING	AASHTO PGDHS EX 10-2 [1]
ACCEL LANE LENGTH (ENTERING US 160)	CDOT TABLE 10-4, 10-5 [2]
ACCEL LANE TAPER	300'
DECEL LANE LENGTH (ENTERING US 160)	CDOT TABLE 10-3, 10-5 [2]
DECEL LANE TAPER	15:1 to 25:1
HORIZONTAL CURVES	
MAXIMUM SUPERELEVATION	8%
VERTICAL CURVES	
CREST (K)	CDOT TABLE 3-1 [2]
SAG (K) (for Headlight Sight Distance)	CDOT TABLE 3-1 [2]
MAX. GRADE DIFFERENCE REQUIRING NO CURVE	0.2%
STOPPING SIGHT DISTANCE (FT)	CDOT TABLE 3-1 [2]
GRADE	
MINIMUM	0.5%
MAXIMUM	7%
PAVEMENT CROSS SLOPE	2%
CROSS SECTIONAL ELEMENTS	
NUMBER OF LANES	1-2
LANE WIDTH (FT)	15' MIN LANE, 20' MIN PVMT
INSIDE SHOULDER WIDTH (FT)	4'
OUTSIDE SHOULDER WIDTH (FT)	6' MIN FOR 1 LANE 8' MIN FOR 2 LANES
CLEAR ZONE WIDTH (FT)	30
SIDE SLOPE DISTANCE "Z" (FT) (Where Applicable)	12
SIDESLOPE (MAXIMUM)	
CUT	4:1 DES. / 3:1 MAX
FILL	4:1 DES. / 3:1 MAX

1. AASHTO A Policy on Geometric Design of Highways and Streets (2004)
2. CDOT Design Guide (2005)

5.3 Drainage/Water Quality

5.3.1 Roadway Drainage Design Criteria

Several drainage design features will be utilized to adequately collect, route, and treat stormwater runoff tributary to this project site. Drainage features to be constructed with the evaluated alternative alignments may include roadside ditches, cross culverts, side drains, and storm sewer systems. A discussion of the design and the criteria utilized for each roadway and alignment will be included in this section.

The roadways of US 550 and US 160 are within CDOT’s jurisdiction, while CR 220 and the frontage road are under La Plata County’s jurisdiction. County design standards require that road structure design be in accordance with current CDOT criteria and procedures. Therefore, drainage design will meet CDOT's standards for the roadways.

Currently, CDOT drainage design requirements are dictated by the 2004 edition of the *Drainage Design Manual.* The design team referenced this manual in determining the design storm frequency for the proposed roadway improvements, which are listed in **Table 5-4**.

Table 5-4: Roadway Drainage Design Criteria

Roadway	Jurisdiction	Roadway Classification	Storm Event	
			Minor	Major
US 550	CDOT	Arterial	10-Year	50-Year
US 160	CDOT	Arterial	10-Year	50-Year
CR 220	La Plata County	Collector	10-Year	25-Year
Frontage road	La Plata County	Local	10-Year	25-Year

With the diverse use of drainage facilities—roadside swales, storm sewer networks, cross drains, and side drains—drainage computations for a minor storm event were equivalent to the 10-year recurrence interval, and computations for the major event were the 25-year, 50-year, and the 100-year intervals. For more information regarding drainage design and assumptions, see the Drainage Report in Appendix N.

5.3.2 Hydrologic Design Criteria

Though storm sewer networks are not routinely suggested in rural areas due to cost of maintaining them, storm sewer networks may be necessary in this project due to the *2006 US 160 EIS* commitment to provide Tier 1 Water Quality (see **Section 5.3.5**, below). For this project, storm sewer networks were designed in accordance with CDOT drainage design criteria, which have been summarized in **Table 5-5**.

Table 5-5: CDOT Storm Drain Design Criteria

Road Classification	Design Element	CDOT
All	Minor storm design	10-yr.
	Major storm design	100-yr.
	Minimum allowable lateral pipe size	15 in.
	Minimum allowable trunk line pipe size	18 in.
Arterials	Minor storm max. spread width	Width of roadway shoulder
	design at sag	50-yr.
	Maximum spread width at sag	Width of roadway shoulder + 3 ft.
Collectors	Minor storm max. spread width	Width of roadway shoulder
	Design at sag	10-yr.
	Maximum spread width at sag	½ of driving lane
Local	Minor storm max. spread width	½ of driving lane
	Design at sag	10-yr.
	Maximum spread width at sag	½ of driving lane

CDOT defines a roadside ditch as an open channel usually paralleling the highway embankment and within the limits of the highway right-of-way. In rural areas, roadside ditches are commonly used as channels utilized to route flows. CDOT's regulations state that a roadside ditch should have the capacity to convey the 10-year storm event with a minimum of one foot of freeboard; when within clear zone of the roadway, the side slopes of ditch should be recoverable. For more information regarding hydrologic design and assumptions, see the Drainage Report in Appendix N.

5.3.3 Wildlife Crossings

The *2006 US 160 EIS* requires a wildlife crossing beneath US 160 where it crosses Wilson Gulch. This crossing must accommodate large animals, such as deer and elk, to maintain historic migration paths. The crossing requires a clear height no less than 12 feet over a 20-foot-wide bench constructed of native material. The bench must be high enough to escape flooding during typical storm events.

In addition to the large-animal crossing on US 160 at Wilson Gulch, the *2006 US 160 EIS* requires a series of small-mammal crossings, spaced approximately 500 feet to 1,000 feet apart, along the proposed US 550 alignment within the project limits. These crossings, which are essentially culverts, shall have a minimum of 12 inches of native soil above the pipe bottom to encourage the animals to use them. They should not carry stormwater flows. As such, they will require additional roadside ditches or other routing measures in areas where design flow elevations will remain below the invert of the crossing.

5.3.4 Floodplains

There are no Federal Emergency Management Agency (FEMA)-regulated floodplains within the project limits.

5.3.5 MS4 Requirements

As stipulated in the *2006 US 160 EIS* and the *2012 SFEIS*, this project must satisfy the requirements for Tier 1 water quality as outlined in CDOT's Municipal Separate Storm Sewer System (MS4) Discharge Permit. This permit seeks to reduce the discharge of pollutants from areas of new highway development and significant redevelopment by requiring the implementation of permanent, post-construction best management practices (BMPs). For Tier 1 projects, Maximum Design Criteria requires that the project either provide 100 percent of the water quality capture volume (WQCV), which is equal to the first ½ inch of runoff from the impervious surfaces associated with the project, or implement BMPs to remove at least 80 percent of the average annual load of total suspended solids (TSS) from these areas.

5.4 Typical Sections

5.4.1 US 550

Roadway Elements

As a Rural Principal Arterial (AASHTO classification) and major regional truck route, the typical section for US 550 must accommodate high speeds, heavy truck traffic, and peak traffic demand. According to the *CDOT Design Guide*, Table 4-1, the typical section for US 550 should be a four-lane roadway with 12-foot lanes and 10-foot outside shoulders (2005, pp. 4-6). At the CR 220 intersection, auxiliary lanes should include both right-turn acceleration and deceleration lanes and left-turn acceleration and deceleration lanes. Shoulder width adjacent to auxiliary lanes, per the CDOT State Highway Access Code (CDOT, 1988, p. 54), is four feet.

To tie in with the typical section defined in the *US 550 EA* (CDOT; FHWA, 2005), all of the alignments have a 46-foot-wide divided median south of CR 220, as shown in **Exhibit 5-1**. The RGM variation continues with this same divided median the entire length into the Grandview interchange.

North of CR 220, both the RGM6 and R5 variations transition to a typical section with a barrier-separated median, as shown in **Exhibit 5-2.** Both alternatives have 8-foot inside shoulders adjacent to the median barrier. The transition to a barrier-separated section on RGM6 helps to minimize impacts to wetlands and historic property by decreasing the roadway footprint. On the R5 alignment, the transition to a barrier-separated section is designed to accommodate a narrower section to minimize the need for additional retaining walls.

Permanent Water Quality Elements

In the *2006 US 160 EIS* (CDOT; FHWA, 2006), CDOT committed to Tier 1 water quality, and the design team has ensured that all typical sections will accommodate this requirement. In many cases, this will require double ditches to carry onsite flow to treatment areas while allowing off-site flow to bypass treatment. Ditches immediately adjacent to the roadway have a 6:1 foreslope and a 4H:1V backslope and are three feet deep. This depth accommodates CDOT's 1-foot freeboard requirement. Where a second ditch is required, a 6-foot bench is provided between the two ditches. The second ditch has 4:1 foreslopes and backslopes and is also three feet deep. In places where very little offsite water is tributary to the roadside ditches, the bypass ditch was eliminated to help minimize historic property and right-of-way takes. See Appendix N for additional information regarding drainage.

Geotechnical Recommendations for Side Slope Elements

Geotechnical testing was completed in the project area. The approximate elevations were mapped where the material strata change. Cuts through the sandy clay overburden soil and the underlying alluvial gravel will have heights ranging from less than 5 feet to about 60 feet. Cuts in the claystone/sandstone bedrock will range from less than 5 feet to about 100 feet.

Un-retained cut and fill slopes should be graded at 3H:1V or flatter to create stable slopes, reduce erosion, and promote re-vegetation.

Tiered retaining walls with a maximum tier height of 30 feet and 15 foot wide benches between tiers were used to evaluate the retained cut slopes in the bedrock. The 30-foot tier height limit will aid in constructability and is similar to other walls in the area along US 160. Bench widths of 15 feet, sloped at 10H:1V, will facilitate construction of the support system and provide room for future access between tiers for maintenance. Wall facing should have a batter of 1H:12V.

Tiered cuts in bedrock with total heights of up to 60 feet can be supported by soil nail wall systems. Use of post-tensioned tie-back anchors may be more efficient than soil nails for walls in rock cuts with heights greater than 50 feet. The extent of soil nails and tie-back anchors behind the cut face should be considered when estimating the right-of-way requirements for retaining wall construction.

Retaining walls to support embankment fills can be cast-in-place or mechanically stabilized earth (MSE) walls. Fill wall heights should not exceed about 60 feet and walls with total heights greater than 30 feet should be tiered in a manner similar to cut walls. Bridge structures should be considered where embankment fill heights would be in excess of 40 feet.

All alignments and variations were modeled using the same set of base templates to promote consistency in the design and provide an expanded understanding of the true level of impacts to the surrounding areas. See Appendix M for additional geotechnical information.

Pavement Design

The construction plans for the US 160/US 550 interchange (CDOT Project NO. NH 1602-114) show that the design pavement section for Ramp A consists of 8 inches of hot mix asphalt (HMA) over 6 inches of Aggregate Base Course (ABC) (Class 6) over 18 inches of ABC (Class 2). The required pavement structural section for the proposed US 550 should be assumed the same as for Ramp A for preliminary design purposes.

5.4.2 R5 Interchange Ramps

All individual ramps have 15-foot lanes with 4-foot inside shoulders and 6-foot outside shoulders. Ramp A is the existing ramp from eastbound US 160 to the Grandview interchange. In the R5 interchange design, Ramp L exits northbound US 550, then has a weave movement with traffic from Ramp A. Traffic on Ramp L can either weave to enter eastbound US 160 or stay on the ramp to go through the Grandview interchange. The introduction of the weave movement also allows Ramp A traffic to rejoin eastbound US 160 traffic. Where Ramp L and Ramp A are merged, the section consists of a 4-foot inside shoulder, two 12-foot lanes, and a 6-foot outside shoulder.

5.4.3 CR 220 and Frontage Road

The existing County road has lane widths as narrow as nine feet in some areas, with little to no shoulder. The portion of road on CR 220 to be reconstructed has a typical section based on La Plata County criteria, with 12-foot lanes and 4-foot shoulders. The same typical section was utilized for the frontage road west of US 550 on top of Florida Mesa.

Pavement Design

La Plata County's standard pavement section is 5 inches HMA over 6 inches ABC (Class 6). This is the section assumed for preliminary design purposes.

5.5 WORKS CITED

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List of Exhibits