4.0 Major Design Features of the Recommended Alternative

4.1 Introduction

This chapter will explore the major design features associated with the recommended alternative. Appendix B contains typical sections for the recommended alternative. Appendix C contains plan and profile sheets at 1"=200' scale for the recommended alternative.

4.2 Design Controls

The mainline reconstruction will be designed to meet ADOT and AASHTO design criteria. Table 46 presents the preliminary mainline and ramp design criteria used to develop the recommended alternative.

Table 46 – Preliminary I-40 Design Criteria

DESCRIPTION OF CRITERION	VALUE FOR DESIGN
Design Year:	2040
Elevation Range:	6100 feet to 7350 feet
Level of Service: Rolling Terrain : (MP 183.00-192.55) (MP 204.86-214.00) Urban / Fringe Urban Area: (MP 192.55-204.86)	 B (RDG, Table 103.2A) B (RDG, Table 103.2A) C - D (RDG, Table 103.2A)
Design Speed: Mainline: (MP 183.00-192.55) (MP 192.55-204.86) (MP 204.86-214.00) Ramp Exit at Mainline Gore: Ramp Entrance at Mainline Gore: Ramp Body: Ramp Terminus: Cross Road:	 75 mph 65 mph 75 mph Mainline design speed minus 5 mph (RDG, Section 503.3) Mainline design speed minus 10 mph (RDG, Section 503.3) 50 mph (RDG, Section 503.3) 35 mph (RDG, Section 503.3) 40 mph, but not less than design speed of cross road approaches to the interchange
Lane Width:	12 feet (RDG, Section 301.3)
Shoulder Width: Outside Shoulder Inside Shoulder	(RDG, Table 302.4) (Truck DDHV > 250) 12 ft. (incl. 2' offset to barrier) (3 or more lane section) 10 ft. + 2' offset to barrier (adjacent to auxiliary lane and/or 2-lane section) 12 ft. (incl. 2' offset to barrier) (3 or more lane section) 4 ft. + 2' offset to barrier (2-lane section)
Superelevation: (Elevation > 6000 Ft)	 e_{max}=0.060 '/ft. (RDG, Table 202.1B)
Median Width:	84 feet desirable (50 feet minimum) (RDG, Section 304.1, Figure 304.3B)
Median Barrier:	Required if median width ≤ 75 feet and natural barriers are not present with 3 or more lanes in each direction (RDG, Section 304.4)
Minimum Horizontal Curve Length: MP 183.00-192.55 MP 192.55-204.86 MP 204.86-214.00	15 x design speed (mph): (RDG, Section 203.5) 1125 feet 975 feet 1125 feet
Maximum Degree of Curve: MP 183.00-192.55 MP 192.55-204.86 MP 204.86-214.00	 2°18' (RDG, Table 202.3B) 3°27' (RDG, Table 202.3B) 2°18' (RDG, Table 202.3B)
Maximum Gradient: Mainline: MP 183.00-192.55 MP 192.55-204.86 MP 204.86-214.00 Ramps: Upgrade Downgrade	 4% (RDG, Table 204.3) 3% (RDG, Table 204.3) 4% (RDG, Table 204.3) 4% desirable, 6% maximum (RDG, Section 504.1) 5% desirable, 6% maximum (RDG, Section 504.1)
Normal Cross Slope:	2.0% (RDG, Section 301.2, Figure 306.2)
Side Slope:	Std C-02.10, Std C-02.20 (RDG, Figure 306.2) plus, when applicable, cut slope modifications for rockfall containment and fill slope flattening to eliminate need for guardrail
Minimum Vertical Curve Length (mainline):	1000 feet (RDG, Table 204.4)
Taper Rate (Lane Drop): MP 183.00-192.55 MP 192.55-204.86 MP 204.86-214.00 Taper Rate (Lane Addition):	Design speed (mph) to one: (RDG, Section 207) 75:1 65:1 75:1 25:1 (RDG, Section 207)

DESCRIPTION OF CRITERION	VALUE FOR DESIGN
Horizontal/Lateral Clearances: Clear Zone / Recovery Area Width:	(RDG, Section 308, Section 303.2, Table 303.2) 30 feet
Minimum Vertical Clearance (Mainline): Overpass Underpass Sign Structure Railroad	(RDG, Section 206.4) 16.5 feet 16.5 feet 18.0 feet 23.5 feet
Type of Access Control:	Full Access Control
Right-of-Way Width:	400 feet

4.3 Horizontal and Vertical Alignments

4.3.1 Typical Section

The proposed typical section for the new widened roadways will consist of 12-foot travel lanes and 12-foot inside and outside shoulders. Three lanes will be provided in each direction from MP 183.7 to MP 208.4 with a total width of 60 feet. The typical section for the segments which are not widened to three lanes (MP 183.0 to 183.7 and MP 208.4 to 214.0) will consist of two 12-foot travel lanes, a 4-foot inside shoulder, and a 10-foot outside shoulder.

Within the three-lane section, an auxiliary lane is proposed between traffic interchanges in several locations. With the addition of the 12-foot auxiliary lane, the outside shoulder will be reduced from 12 feet to 10 feet. The segments with recommended auxiliary lanes include the Flagstaff Ranch TI to the new Woody Mountain TI (MP 192.56-MP 193.47), from the I-40/I-17 system TI Ramp N-E to the new Lone Tree TI, and from the new Lone Tree TI to the Butler TI (MP 195.5-MP 198.28).

The standard cross slope will be 0.020ft./ft. in tangent sections. Superelevation rates for horizontal curves have been designed based on the RDG superelevation tables. Most of the existing curves are superelevated at rates that differ from the current RDG requirements and will require cross-slope modifications. In order to modify the cross slopes in the sections of I-40 where the roadway will remain on its current horizontal and vertical alignments, variable-depth milling will be required to adjust the cross-slope.

In addition, superelevation transitions at the curve entrances and exits need to be lengthened due to the increased roadway width.

Median Width

Median width is defined as the distance between opposing travel lanes. The median dimension includes the inside shoulder widths. Proposed median widths are summarized in Table 47.

Table 47 – Median Width

MP	MEDIAN WIDTH (FEET)	BARRIER	NOTES
183.0 – 184.3	133 to 395	None	
184.3 – 188.2	142	None	
188.2 – 189.2	142 to 189	None	Rockfall mitigation area
189.2 – 190.2	142	None	
190.2 – 191.2	58 to 148	Concrete median barrier req'd for median < 75'	Riordan RR OP
191.2 – 192.8	148	None	
192.8 – 196.3	148 to 395	None	
196.3 – 198.4	118 to 580	None	
198.4 – 199.6	118 to 148	None	Rockfall mitigation area
199.6 – 207.0	148	None	
207.0 – 208.4	96 to 172	None	Cosnino TI
208.4 – 210.6	172	None	
210.6 – 211.3	82 to 172	None	Winona TI
211.3 – 214.0	82	None	

4.3.2 Horizontal Alignment

ADOT's Photogrammetry & Mapping Section prepared topographic mapping for the project and used it to define a best-fit centerline for the existing I-40 alignments. This best-fit centerline was used as the basis for the new I-40 centerline.

As-built plans indicate that many of the existing curves were designed with spiral curves. Since the reconstructed roadway should meet current cross-slope criteria, the alignment was modified to reflect current design practice on the usage of spiral curves. Curves with a degree of curvature of 2°00' or less do not warrant spirals; therefore, spirals were not used for these curves.

Stationing for the new alignments approximates the as-built centerline stationing since the curvature and offset differences in the alignments prevent an identical match. Station equations were established periodically to calibrate the new alignment stationing to the record drawing stationing.

The plan sheets in Appendix C illustrate the proposed horizontal alignments with stationing, geometric curve data, and superelevation rates. The existing alignments are not shown from MP 183.0 to MP 208.4. The existing centerline is the controlling point of reference from the eastern limit of the three-lane section to the eastern project limit (MP 208.4 to MP 214.0).

4.3.3 Description of Proposed Widening

4.3.3.1 Introduction

The I-40 mainline lies between approximately 7130 feet elevation at its western end (MP 183.0) and approximately 6200 feet at the eastern end (MP 214.0). The project passes through rolling terrain in Coconino County, ascending to the interstate's highest elevation at the Arizona Divide near MP 190.0, then descending toward the City of Flagstaff, the system interchange with I-17, and eastward into rural areas.

AASHTO's *A Policy on Geometric Design of Highways and Streets* and ADOT's *Roadway Design Guidelines* provide guidance on the maximum allowable grade for a given design speed based on the terrain classification and surrounding development. In rural rolling terrain, the maximum grade is 4% for design speeds of 65-75 mph. In urban/fringe urban conditions, the maximum grade is 3% for a design speed of 65 mph.

The mainline horizontal and vertical alignments will be modified as needed to meet a 75-mph design speed in the rural segments and a 65 mph design speed in the urban/fringe urban segment. The elements of the mainline recommended alternative are presented below. The proposed improvements are described from west to east.

Proposed improvements to existing traffic interchanges and the proposed new traffic interchanges are referenced in the mainline discussion but are described in more detail in Section 4.12, Traffic Interchanges.

4.3.3.2 Mainline I-40 (Horizontal and Vertical)

Improvements to the grades along the western and eastern rural rolling segments are recommended where the grade exceeds the recommended 4%. Within the urban/fringe urban segment, one location where the eastbound and westbound grades exceed the recommended 3% will remain and a design exception will be requested. These three locations are discussed in more detail below.

The recommended pavement structural sections provide opportunities to reconstruct sections of the corridor to meet current geometric standards. Approximately 7.5 miles of the 10-mile urban/fringe urban section are recommended for complete reconstruction with a doweled Portland cement concrete pavement (PCCP). The total replacement of the pavement will allow horizontal and vertical geometric improvements to be made. Superelevation improvements are required for most curves. The improvements would result in I-40 meeting horizontal and vertical design speeds of 65 mph.

Horizontal alignment improvements will be accomplished mostly within the existing R/W; however, the addition of through and auxiliary lanes, new traffic interchanges, improvements to cut slopes and rockfall areas, and other improvements will require approximately 155-157 acres of additional R/W.

4.3.3.3 I-40 Geometric Improvement Recommendations (MP 183 to MP 193)

This section addresses the western project area: alignments, rockfall mitigation, and structures which require rehabilitation or replacement due to age and load capacity limitations. The improvements begin at the proposed new Camp Navajo TI (MP 183.66). Both the eastbound and westbound roadways will remain in the existing two-lane configuration west of the new Camp Navajo TI, where the third lane will be added in the eastbound direction at the eastbound entrance ramp. The mainline will shift to the inside to maintain the outside edge of pavement. The large open median provides adequate width to widen the existing eastbound roadway without the need for additional R/W. In the westbound direction, the third lane will be dropped at the westbound exit ramp for the new Camp Navajo TI. The westbound alignment, similar to the eastbound direction, shifts to match the existing westbound alignment within the limits of the new traffic interchange. The proposed three-lane section follows a relatively straight alignment and has a gentle vertical grade to the east.

At the existing Bellemont TI (MP 185.15) the third lane will continue through the median. The existing interchange will require modifications to accommodate the widening. Both existing structures will be replaced; more modifications to the interchange are discussed in greater detail in Section 4.12.3.

From MP 188.08 to the east, the existing roadway geometry will be modified to meet current design standards and mitigate two rockfall locations. The westbound roadway profile will require more extensive reconstruction to flatten the existing 4.75% grade to the maximum recommended grade of 4.0%. There are two locations where the existing cut slopes are experiencing stability issues; mitigation is recommended at these locations as listed in Table 55 in Section 4.9, Geotechnical. Realignment of the westbound horizontal and vertical alignments and implementing the rockfall mitigation measures will require new R/W from CNF on the north side of I-40. The westbound roadway will be shifted to the north to reduce impacts to the rock median and the adjacent eastbound roadway at a lower elevation. The rock cut on the outside will be laid back at 3:1 with a crown ditch at the top of the slope. This 3:1 slope is conservative and was recommended because field tests have not been performed and geotechnical recommendations have not been finalized.

Photograph 4-1. I-40 near MP 188.8, looking west.

In the eastbound direction, the horizontal and vertical alignments will be modified to improve the superelevation, reduce impacts to the rock cut in the median, and improve the vertical stopping sight distance. The eastbound horizontal curvature will be slightly flatter than the existing alignment. A retaining wall will be required along the south side of the eastbound roadway to avoid impacts to the BNSF railroad R/W (Station (Sta.) 1785+00 to Station 1830+00, MP 188.2 to MP 189.0).

Just west of the A-1 Mountain TI (MP 190.54), pavement widening transitions to pavement reconstruction. Due to the close proximity of the interchange to the structures over the BNSF railroad, the mainline profile requires modification to provide vertical clearance for the new deeper railroad structures. The replacement of the railroad structures provides the opportunity to flatten the horizontal curves, improve superelevation, and improve the vertical stopping sight distance between the A-1 Mountain TI and the West Flagstaff TI (MP 191.69).

The reconstruction through the Riordan railroad crossing area begins at MP 189.79 and ends at MP 191.68 (Sta. 1870+00 to Sta. 1986+00). This section of horizontal alignment will be modified to smooth the existing "S-curve" over the BNSF railroad tracks and improve the superelevation. These modifications will improve drainage patterns across the roadway and structure, where the current configuration reportedly allows the bridge deck to freeze at night following periods of snowmelt during the daytime hours. In addition, the sharp curves and low superelevation at this location are not consistent with drivers' expectations because the horizontal alignments in both directions are relatively straight for miles approaching this location.

Because the median width will decrease to 58 feet, median barrier will be required in this area. ADOT's *Roadway Design Guidelines* specify that median barrier is warranted for divided highways with three or more lanes in each direction and median widths less than 75 feet wide. Therefore, median barrier will be required for approximately 1500 feet where the median width is less than 75 feet.

The reconstruction of the eastbound and westbound roadways will continue eastward through the West Flagstaff TI to approximately MP 192.0. The West Flagstaff TI bridge structures cannot be widened and are recommended for replacement. Because of the new longer spans and deeper structures, the mainline profiles will be raised approximately two feet. The eastbound loop entrance ramp will be modified to tie in at the new elevation. The new eastbound mainline structure will accommodate the wider roadway and the new parallel entrance ramp. Similarly, the new westbound structure will provide width for the three travel lanes and a new parallel-type exit ramp. The westbound exit loop ramp profile will also be raised to tie in to the new westbound profile.

East of the realigned S-curve section, the eastbound and westbound horizontal alignments are parallel with 166 feet between the new centerlines. From MP 191.68 to MP 192.81 (Sta. 1986+00 to Sta. 2029+96), the roadways will be widened to the inside. The outside edge of the existing pavement will be held constant and the earthwork for the inside widening will be contained within the existing median.

The new 60-foot wide roadways will be carried east through the Flagstaff Ranch TI (MP 192.56). The ramp gores on the west side of the interchange will not require modification. The eastern ramps at the Flagstaff Ranch TI will be modified to tie into the modified mainline alignments new Woody Mountain TI ramps.

The Flagstaff Ranch TI (MP 192.6) is generally where the terrain classification transitions from rolling rural to urban/fringe urban. The posted speed limit in the eastbound direction drops to 65 mph from 75 mph and increases from 65 mph to 75 mph in the westbound direction.

4.3.3.4 I-40 Geometric Improvement Recommendations (MP 193 to MP 203)

East of the Flagstaff Ranch TI, the eastbound and westbound alignments shift toward the median. This shift is necessary to accommodate the proposed improvements at the new Woody Mountain TI, which are discussed in more detail in the Traffic Interchanges section of this report.

The eastbound horizontal alignment will be shifted approximately 75 feet. In addition, the profile will be lowered eight feet to improve the grades and sight distance along the Woody Mountain Road cross road. The westbound horizontal alignment will shift toward the median approximately 42 feet. The westbound profile will also be lowered approximately eight feet at Woody Mountain Road. The new structures at Woody Mountain Road will provide the required horizontal and vertical clearances.

Near MP 194, the eastbound and westbound full reconstruction transitions back to the existing alignments and inside widening on the downgrade east toward the I-40/I-17 system interchange. The westbound alignment will require additional width for the extended parallel entrance ramps from the system interchange.

From MP 195.0 to MP 202.5 (Sta. 2145+00 to 290+00), the pavement structural section changes from AC widening to dowelled PCCP.

Eastbound I-40 will be 60 feet wide through the system interchange. The profile of the eastbound alignment will be raised to accommodate a new, deeper structure over I-17. The horizontal alignment will be shifted slightly to the north to accommodate the parallel-type entrance ramp for the northbound I-17 to eastbound I-40 ramp and allow the wider roadway to pass between the piers of the westbound I-40 to southbound I-17 directional ramp. The parallel ramp ends just west of the northbound I-17 to eastbound-I-40 ramp merge. The two-lane north-to-east entrance ramp will transition to auxiliary lanes between the system TI and the new Lone Tree TI (MP 196.7). The outermost auxiliary lane will exit to the new two-lane Lone Tree Road exit ramp. The other eastbound auxiliary lane has the option to exit; otherwise, it will merge into the mainline west of the new Lone Tree Road cross road.

Westbound I-40 through the system interchange is shifted to the south to accommodate the braided ramp configuration of the new Lone Tree TI and the entrance ramps from I-17, as well as fit the new 60-foot wide roadway through the existing piers of the westbound I-40 to southbound I-17 directional ramp. The westbound taper-type entrance ramps will be converted to parallel-type ramps. The northbound-to-westbound loop entrance ramp will require modification, including re-profiling the gore area to match into the raised I-40 profile.

Photograph 4-2. I-40/I-17 system TI, looking west.

In the westbound direction, an auxiliary lane will be added to the three-lane section between the system interchange and the new Lone Tree TI.

The existing Lone Tree Road overpasses (MP 196.26) will be replaced with two new structures for mainline traffic and one new structure for the C-D road/braided ramp.

The reconstructed eastbound and westbound roadways will include auxiliary lanes from the new Lone Tree TI over the widened Rio de Flag bridges (MP 197.43) to the Butler TI (MP 198.28).

The eastbound and westbound structures at the existing Butler TI will be widened to the inside for the new 60-foot wide roadway.

The new eastbound and westbound alignments will continue to follow offset alignments from the Butler TI to 2000 feet west of the existing Fourth Street underpass. The existing rock cuts approaching the Fourth Street crossing have been identified as rockfall mitigation locations. To mitigate the existing rock cut slopes without impacting the developed properties adjacent to ADOT's R/W, the eastbound and westbound horizontal alignments will be shifted 29 feet toward the median. The shift will provide additional width for 25-foot rockfall containment ditches on both the outside and median side of the eastbound and westbound roadways. The cut into the median rock will be sloped at 1H:1V to maintain as much of a natural barrier as possible between the eastbound and westbound alignments.

Photograph 4-3. I-40 near Fourth Street, looking east.

After crossing beneath Fourth Street, the mainline roadway will transition back toward the existing alignments over 1500 feet. The shifts are achieved by angle breaks less than 0°45'.

As the alignments approach the Country Club TI (MP 201.10), the westbound profile will be lowered approximately six inches to provide the recommended vertical clearance for the new three-lane roadway under the widened structure. The eastbound profile will follow the existing vertical alignment.

The PCCP section will end near the new US 89 TI western ramps at MP 202.55. From this point east to the end of the three-lane segments, the existing AC pavement will be widened.

4.3.3.5 I-40 Geometric Improvement Recommendations (MP 203 to MP 214)

The new eastbound and westbound alignments will continue to follow 14-foot offset alignments from east of the new US 89 TI to the end of the three-lane section (MP 208.41). The widened roadway through the existing Walnut Canyon TI (MP 204.87) will require replacement of the existing structures to provide the horizontal and vertical clearances for the new roadway widths. Additional improvements proposed at the Walnut Canyon TI are discussed in Section 4.12, Traffic Interchanges.

East of the Walnut Canyon TI, the inside widening will continue to MP 207, just west of the existing Cosnino TI. The eastbound horizontal alignment will remain offset 14 feet from the existing centerline. However, the proposed improvements at the Cosnino TI, discussed later in this chapter, require that the westbound alignment be shifted 12 feet to the north through the interchange and that the vertical profile be lowered 1.5 feet. The proposed interchange reconfiguration consists of removing and re-aligning the westbound loop exit ramp and re-aligning the westbound entrance ramp. These improvements will allow the existing cross road structure to remain in place and the 60-foot wide westbound roadway to pass between the spread footings of the Cosnino bridge piers. The profile adjustment will provide the recommended vertical clearances required at this location. This shift in the westbound alignment will require approximately 3300 feet of total mainline reconstruction.

Photograph 4-4. I-40 at Walnut Canyon TI, looking east.

Approximately one mile east of the Cosnino TI, the third lanes are dropped and the roadways transition back to the existing two-lane roadways. From MP 208.4 to the study's eastern limit, MP 214.0, rehabilitation of the existing pavement is recommended.

Modifications are proposed at the Winona TI (MP 211.16); however, the proposed improvements are not driven by the I-40 mainline improvements since the existing two-lane configuration will be unchanged in this segment. The interchange modifications are necessary because the existing structure, built in the 1960s, has been classified as functionally obsolete due to non-conforming underclearances and an Inventory Load Rating less than HS-20. These interchange improvements are discussed in greater detail later in this chapter.

4.3.4 Summary of Widening and Geometric Recommendations

Throughout the length of the project, widening to each side of each roadway was evaluated. The recommended alternative is to widen each roadway to the side with the least amount of earthwork required while maintaining or improving the existing horizontal geometry and minimizing impacts to adjacent lands.

Segments of the corridor are recommended for total reconstruction because of recommended pavement structural section changes or geometric improvements that cannot be achieved by widening.

Table 48 provides a summary of the roadway widening recommendations.

Table 48 – Mainline I-40 Widening Summary

MP	COMMENTS
Inside Widening	
183.6 – 188.1	Widening shifts the roadway toward the median to allow the third lane to be added, holding the existing outside edge of pavement.
189.4 – 189.8	AC widening segment between rockfall mitigation area realignment and railroad crossing realignment
191.6 – 192.8	AC widening segment between railroad crossing/West Flagstaff TI realignment segment and Woody Mountain Road realignment.
194.0 – 195.0	AC widening segment between Woody Mountain Road realignment segment and PCCP segment
202.6 – 208.4	AC widening segment east of PCCP reconstruction segment
Outside Widening, Widening to Both Sides, and/or Reconstruction	
188.1 – 189.4	Re-align/reconstruct roadways to improve horizontal geometry and vertical stopping sight distance
189.8 – 191.6	Re-align/reconstruct roadways to improve horizontal geometry and modify profile to provide vertical clearance for new railroad structures and improve stopping sight distance.
192.8 – 194..0	Shift alignments toward median and lower profile to accommodate new Woody Mountain TI.
195.0 – 202.6	Horizontal and vertical geometry is modified to accommodate new, deeper structures and minimize impacts to existing ramps through the system TI, accommodate new auxiliary lanes and the new Lone Tree TI. Alignments are shifted to median near Fourth Street for outside rockfall mitigation. WB profile to be lowered near Country Club Road to improve vertical clearance. This section will be reconstructed with PCCP in its entirety; offset horizontal geometry will help with constructability.

Table 49 provides a description of the horizontal curves to be realigned.

Table 49 – Curve Realignments

MP	EXISTING CURVE	PROPOSED DEGREE OF CURVE	COMMENTS
Eastbound			
190.7 – 191.2	2°00' + 300 ft. spirals	0°45'	Straightens the existing alignment through the Riordan railroad crossing.
192.8 – 193.9	0°30'	0°15'	Realignment through Woody Mountain TI. Flat curves maintain normal crown through section.
		0°15'	
		0°15'	
197.2	Angle Break		Eliminated angle break in reconstructed PCCP mainline section.
198.4 – 199.6		Angle Break	Realignment at Fourth Street UP to mitigate rockfall hazards without impacting adjacent developed properties. Maintains normal crown through section.
		Angle Break	
		Angle Break	
		Angle Break	
Westbound			
188.2 – 188.6	2°00' + 300 ft spirals	2°00'	Realignment through the S-curve rockfall mitigation.
188.7 – 189.2	1°40' + 333 ft spirals	1°40'	Realignment through the S-curve rockfall mitigation.
190.8 – 191.1	2°00' + 300 ft spirals	1°00'	This realignment straightens the existing alignment through the Riordan railroad crossing.
192.8 – 193.3	0°30'	0°17'	Realignment through Woody Mountain TI. Flat curves maintain normal crown through section.
198.4 – 199.6		Angle Break	Realignment at Fourth Street UP to mitigate rock fall hazards without impacting adjacent developed properties. Maintains normal crown through section.
		Angle Break	
		Angle Break	
		Angle Break	
207.0 – 207.6	1°00'	0°54'	Realignment through Cosnino TI. Flatter curve to split existing pier spread footings to lower profile.

4.3.5 Vertical Alignment

Design guidelines specify that the profile grade line (PGL) is to be located on the axis of superelevation rotation. For the proposed alignments of the widened and reconstructed roadways, the PGL also corresponds to the horizontal control line.

Maximum Grade

From MP 188.2 to MP 188.8 (approximately Sta. 1786+20 to Sta. 1817+90), the existing westbound profile grade will be reconstructed and flattened from 4.75% to 4.0%.

From MP 194.2 to MP 195.0, the eastbound and westbound grades in the urban/fringe urban segment exceed the allowable maximum of 3.0%. The recommended alternative will not flatten these grades because of existing steep terrain and because the adjacent properties are highly developed. The flattening of the steep grades would require major earthwork and construction of large retaining walls to avoid impacts to the surrounding residential and commercial properties. Design exceptions will be requested as described in Chapter 5.

From MP 209.6 to MP 209.8, the westbound roadway grade exceeds the maximum rural rolling terrain criterion of 4.0%. However, the grade in this section will not be modified because this section of roadway is proposed to remain in its existing two-lane (38-foot wide) configuration. The existing pavement will be rehabilitated. A design exception will be requested as described in Chapter 5.

In addition to maximum grade issues, vertical curve length and stopping sight distance have been evaluated. Record drawings indicate that a number of existing curves were originally designed with a vertical curve length of 800 feet. These curves will be reconstructed to a minimum length of 1000 feet to meet current standards where the roadway pavement structural section is to be reconstructed or where there are additional horizontal and vertical geometric modifications to be made at the same location.

Four curves in the eastbound direction and eight curves in the westbound direction do not meet vertical stopping sight distance requirements for a 75 mph design speed. The four eastbound vertical curves will be modified with the proposed improvements. The first (westernmost) of the four curves is a sag curve (MP 188.2 to MP 188.4), which falls within the segment of eastbound I-40 to be realigned to the outside and raised several feet to limit the median cuts between the eastbound and westbound roadways. This segment also includes a retaining wall along the outside edge of pavement to limit impacts to the railroad R/W.

The remaining three curves in the eastbound direction occur in succession from just west of the A-1 Mountain TI to the Riordan railroad crossing (MP 189.8 to MP 190.6). The replacement of the railroad crossing structure requires additional modifications to the mainline. These modifications provide the opportunity to lengthen the existing sag curve and to re-profile the railroad crossing segment to meet the desired design speed of 75 mph.

The first three westbound vertical curves (MP188.1 to MP 190.6) will be improved similar to the eastbound curves. The first two of the three will be reconstructed with the realignment and westbound rockfall mitigation. The third vertical curve is located within the realignment segment associated with the Riordan railroad crossing bridge replacement.

The remaining five westbound vertical curves are east of the proposed widening limits, where only rehabilitation of the existing pavement is proposed. Modifications to the roadway profile through these curves would require substantial reconstruction. Design exceptions will be requested as described in Chapter 5.

Outside of the areas requiring realignment to satisfy the criteria for a 75 mph design speed, the profiles were established as a best-fit match of the existing alignments. By matching the existing alignments as much as possible, slope impacts are minimized and constructability is improved.

Vertical Clearance

There are a number of roadway grade separations throughout the corridor. Structures at some of these grade separations will be replaced. ADOT bridge design guidelines call for a minimum vertical clearance of 16'-6" for new bridges. Bridges requiring widening or major rehabilitation should be upgraded to achieve the 16'-6" minimum vertical clearance. Clearances of 16'-0" may be permitted where truck traffic is low, the pavement underneath is PCCP that will not have an overlay, and no other factors are present that could reduce vertical clearance in the future (e.g., future widening, overlays, or potential for structure settlement).-The roadway profile has been adjusted at new structure locations to provide additional separation between the mainline and cross road to achieve a minimum vertical clearance of 16’-6”.

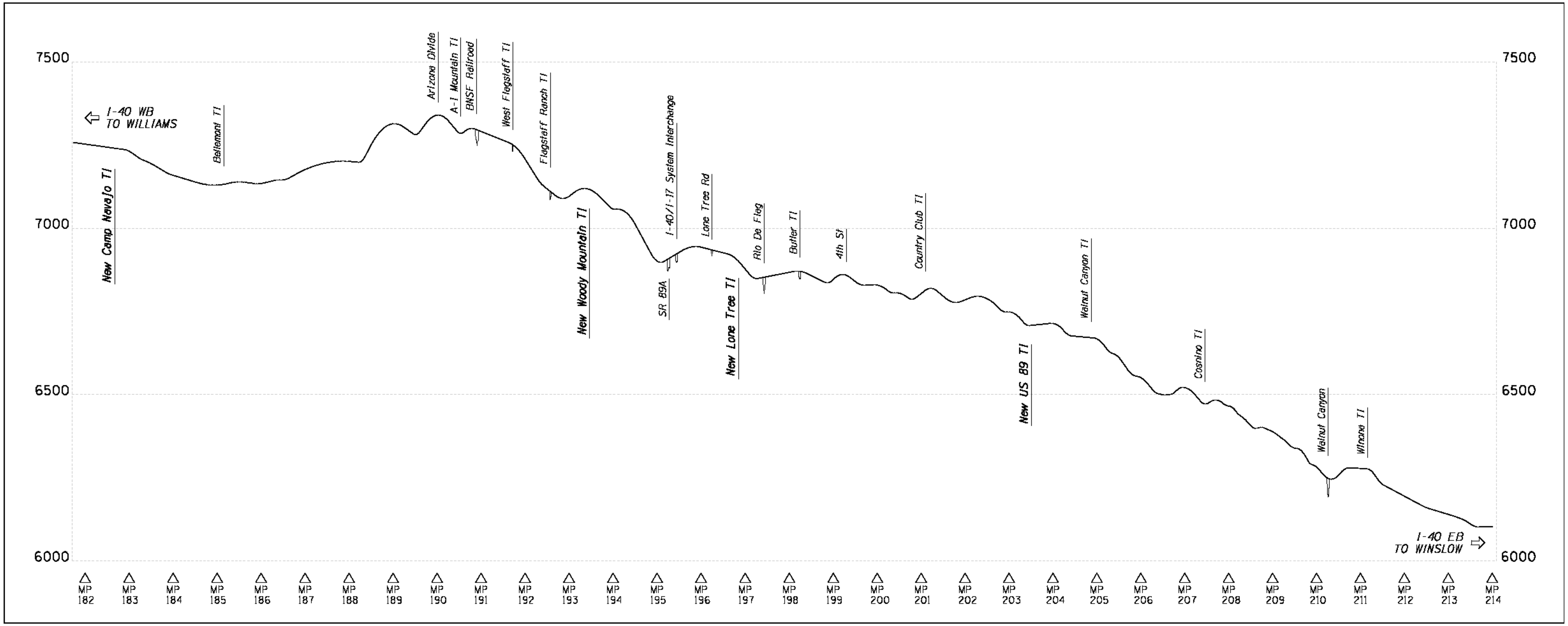
4.4 Access Control

I-40 is a fully access-controlled facility. Modifications to the existing access control are anticipated with these proposed improvements to the corridor. There are a few forest roads within ADOT R/W but outside the access control limits. No access to the interstate is currently provided directly from these roads. The new traffic interchange locations will require access.

Change of Access Reports

Change of access reports for the proposed new interchanges will be required in the future. The change of access report for the new Lone Tree TI was prepared and approved in 1994.

Figure 47 – I-40 Profile



4.5 Right-of-Way

New R/W will be required for construction of the recommended alternative. Right-of-way to be acquired is currently managed by the KNF and CNF and private landowners. R/W lines shown on the plan sheets in the appendices are based on limits of disturbance identified by the conceptual design layout and do not indicate the final R/W requirements or easements necessary for construction. Actual limits will be established during the final design process.

Table 50 lists the preliminary new R/W needs and ownership.

Table 50 – Preliminary Right-of-Way Requirements

MP	DESCRIPTION	WIDTH	AREA (acre)	OWNER(s)
183.5-183.8	New Camp Navajo TI	Varies, 240' max	26.2	KNF
			15.3	Private
185	Bellemont TI	Varies, 384' max	3.1	KNF
			16.2	Private
188-189	S-curve realignment at rockfall mitigation area	Varies, 254' max	18.6	CNF
190.5	A-1 Mountain TI	Varies, 247' max	5.0	CNF
191.7	West Flagstaff TI	Varies, 81' max	1.2	CNF
192	New Woody Mountain TI	Varies, 122' max	3.3	State Land
			8.3	Private
196	New Lone Tree TI	Varies, 310' max	14.1-14.4 *	Ariz. Board of Regents
			4.1-5.4 *	Private
198	Butler TI	Varies, 15'-25'	0.6-1.4 *	Private
201	Country Club TI	87' max	0.4	State Land
202-203	New US 89 TI	Varies, 300' max	3.8	COF
			9.4	State Land
			7.2	Private
204	Walnut Canyon TI	Varies, 200' max	12.2	CNF
			2.3	State Land
207	Cosnino TI	Varies, 70' max	0.9	CNF
			3.1	Private
TOTAL			**155.3-157.7 ***	

* R/W acreage varies depending on which alternative is recommended.

Several culvert extensions may require additional temporary or permanent drainage easements. The location of these easements will need to be identified during final design.

There are a number of section corners in the project area which are in or near the roadway. The monuments shall be preserved or replaced if disturbed by construction.

4.6 Drainage

4.6.1 Introduction

This section summarizes the evaluation of the drainage facilities in the project area and proposed drainage improvements as detailed in the *Preliminary Drainage Report*. Unless identified as an area of special concern, only culverts 36 inches in diameter or larger were evaluated. A total of 37 box culverts, pipe culverts, or pipe culvert sets met these criteria and were evaluated.

Design criteria, hydrology, and hydraulics were considered at each culvert. Culverts under I-40 were designed to convey the 50-year peak discharge following the design procedures outlined in the ADOT *Highway Drainage Design Manual* and the *Roadway Design Guidelines*.

Required drainage improvements consist of adding culverts, extending existing culverts, and relocating existing roadside ditches. The recommended alternative adds supplementary culverts to 10 of the 37 existing culverts that were evaluated.

New onsite drainage facilities will include area type inlets, downdrains, and roadside ditches. In the vicinity of new guard rail installations, curb may be required to intercept roadway sheet flow, and convey the discharges to new spillways and/or new down drainpipes. Onsite drainage facilities will be designed for the 10-year rainfall event.

4.6.2 Culvert Improvements

A hydraulic analysis was completed for the major culverts within the project limits. Table 51 presents the upgrades that could be used at the specified location to convey the design storm. These recommended culvert additions or replacements are preliminary and should be verified during final design.

Table 51 – Recommended Additional Pipe/Culvert Summary

CULVERT ID	MP	EXISTING STRUCTURE SIZE/TYPE	Q_{50} (cfs)	EXST HW/D RATIO	UPGRADE CONTROL	RECOMMENDED ADDITION
2021	184.0	10x8 ft CBC	2117	3.1	HW criteria driven	2-10x8 ft CBC
1002	184.9	3-10x5 ft CBC	2738	3.2	HW criteria driven	2-10x5 ft CBC
1023	185.4	48 in CMP	142	1.8	HW criteria driven	48 in CMP
1026	188.3	36 in CMP	407	81.0	HW criteria driven	8x4 ft CBC
1030	188.0	36 in CMP	407	72.2	HW criteria driven	8x4 ft CBC
2041	200.8	10x6 ft CBC	749	1.6	Pavement elev. driven	10x6 ft CBC
2057	202.8	48 in CMP	313	9.3	HW criteria driven	3-48 in CMP
2095	207.5	6x7 ft CBC			HW criteria driven	1-48 in CMP

Notes: 1. Recommendations based on additional pipes or barrels of appropriate size to achieve the desired HW = 1.5 * D.
2. Proposed additional pipes are based on two drainage criteria:
a. Existing HW/D ratio of 1.8 or greater, and/or,
b. Existing HW is above roadway elevation.
3. In several instances the roadway elevation is very close to the elevation of the top of the structure, where HW = 1.5 * D cannot be achieved. In these cases, the roadway edge or lowest adjacent grade was used as the maximum allowable HW.

4.6.3 Areas of Special Concern

Several drainage concerns were identified by the project team and are addressed below.

MP 184.9, 3-10x5 ft CBC

Near Bellemont, MP 184.9, on the north side of I-40, ponding has been reported upstream of the 3-10'x5' CBC. There is a residential development immediately upstream of the culvert that discharges treated water to this point.

The hydrologic calculations produced a 50-year discharge of 1088 cubic feet per second (cfs). This resulted in a headwater elevation of 7130.5 at the culvert, which meets ADOT criteria. There are separate culverts for the westbound and eastbound lanes. A field review of both inlets did not reveal any unusual elements that may be causing additional upstream ponding.

During the site visit, standing water (greater than one foot) was observed in the culverts. There was also standing water upstream and downstream of the culverts. There is minimal longitudinal slope within the culverts or upstream and downstream of either structure. However, it should be noted that the area did receive a high snowfall amount (over 140 inches reported for Flagstaff) during the winter months and that runoff from snow melt was still occurring within the watershed. Discussions with ADOT maintenance personnel noted that ponding in this area typically only occurs during the snowmelt period in the spring.

Based on the field visit and calculations performed for the structures, a modification of the crossing does not appear to be necessary. With the culvert crossing predating the adjacent subdivision by approximately 40 years, any ponding issues within the adjacent subdivision appear to be a result of the subdivision being built too low in relation to the culvert crossing.

MP 189.4, 12x12 ft CBC

Near MP 189.4, there is a 12'x12' box culvert in a meadow area where the land immediately around the culvert crossing is relatively flat. The general topography slopes from the north to the south.

The culverts under both the westbound and eastbound lanes slope to the south, but the inlet of the box culvert under the eastbound lanes is approximately 3.4 feet higher, than the outlet of the box culvert under the westbound lanes, creating ponding between the two box culverts within the median. A 66-inch CMP crosses I-40 approximately 200 feet west of the box culvert crossing. The inlet elevation of the 66-inch pipe under the eastbound lanes is approximately five feet lower than the inlet elevation of the box culvert. To alleviate flooding within the median, a low flow channel should be constructed between the two box and pipe culvert crossings. The channel will alleviate ponding created by the high inlet elevation of the concrete box culvert.

Photograph 4-5. Inlet of 4-10'x4' box culverts under I-40 near Bellemont.

MP 190.6, 2-8x5 ft CBC

It was reported that the 2-8'x5' CBCs at A-1 Mountain, MP 190.6, were constructed with no longitudinal slope or with a slight adverse slope which allows ponding of water to depths of six to seven feet at times. In addition, a residential development discharges to this point which fills up the roadside ditch system and causes frequent ponding near the large home properties. Adjacent railroad tracks contribute to the poor drainage situation.

The contributing area to the culvert crossing produced a 50-year flow of 1000 cfs. The headwater elevation for the 50-year event is 7291.8, which meets ADOT criteria. The culvert crossing consists of a continuous 2-barrel 8'x5' CBC that spans both the westbound and eastbound lanes. The slope and skew varies within the culvert. Based on field reviews, the inlet is a standard inlet with no unusual characteristics.

There is a drainage ditch from the west that conveys the majority of the flows to the box culvert. The ditch is overgrown with brush and partially obstructed. ADOT maintenance personnel indicated that the ditch was scheduled to be cleaned out soon. Maintenance will alleviate some of the localized ponding issues that occur.

The ditch conveying flows to the box culvert is approximately 7-8 feet deep. Therefore, most of the ponding that results from the culvert inlet hydraulics is contained within the ditch area. Beyond the maintenance activities for the drainage ditch at the inlet, additional improvements do not appear to be necessary.

Photograph 4-6. I-40 Inlet of 2-8'x5' box culverts at A-1 Mountain.

MP 201.8 Multiple Culverts

Two large box culverts under I-40 at approximately MP 201.8 currently pass flows to culverts under Old US 66 and the railroad tracks, which are undersized and cause bottlenecks and ponding in the I-40 R/W (1993 flooding).

The Big Fill Wash area is part of the Rio de Flag watershed. The contributing area is in excess of 110 square miles. The Rio de Flag conveyance corridor is wide, with minimal longitudinal slope in the area where it crosses I-40. The watershed has been studied as part of a FEMA Flood Insurance Study (FIS). The study identified a 50-year flow of 2400 cfs. The existing culverts are 5-barrel 10'x9' CBCs. This 50-year flow produced a headwater elevation of 6752.6, which meets ADOT criteria. Downstream of the I-40 culverts are culverts under the railroad tracks and Old US 66. Each crossing consists of a 48-inch pipe. These culverts are undersized and create an upstream backwater.

The FEMA FIS recognizes the 48-inch culvert under Old US 66 and reduces the peak discharge to account for the effects of flood routing and the large upstream storage volume. The floodplain downstream of the 48-inch culverts reflects the smaller flows. If the 48-inch culverts were upsized, the Rio de Flag downstream of them would need to be reanalyzed to determine the effects of the greater peak flows that would result. However, if the culverts were upsized, it would positively affect the culverts under I-40. Therefore, improvements to the I-40 concrete box culverts do not appear to be necessary.

MP 204.2, Walnut Canyon Bridge

A field review was completed for both bridges that span Walnut Creek. During the visit, no major drainage issues were noted but there were some areas where localized erosion has occurred because of stormwater runoff as can be seen in the picture below. The erosion is along the westbound lanes immediately west of the bridge. The erosion at this location is caused by a gap in the asphalt embankment curb behind the guardrail.

Photograph 4-7. Minor erosion at Walnut Creek.

To alleviate erosion, a continuous embankment curb is recommended from the end of the guardrail to the downdrain at the end of the bridge. Additional erosion was noted at the downdrain both along the abutment face and around the downdrain outlet pipe. It is recommended that an additional downdrain inlet and pipe be added to prevent the single inlet from overflowing. This will also be necessary to handle the additional flows that will reach the downdrain once the localized erosion area along the guardrail is corrected.

Photograph 4-8. Downdrain at westbound abutment.

Photograph 4-9. Exposed downdrain pipe along westbound bridge over Walnut Creek.

4.6.4 Summary

Analysis of the existing drainage crossings and proposed culvert improvements along the I-40 corridor utilized the following methods and criteria:

- ADOT drainage design criteria as described in the ADOT Hydrology and Hydraulics manuals.
- Hydrologic calculations were made with the Rational Method or HEC-1 techniques, based on catchment area. The HEC-1 parameterization used Green and Ampt loss methodology and Clark Unit Hydrograph. NOAA 14 charts were used for determining rainfall.
- Culvert analyses were limited to structures of 36 inches or larger in diameter unless identified as an area of special concern.
- Culvert hydraulic calculations were made to check the existing structure capacity to convey the design flow. A culvert required additional capacity if the headwater (HW) to culvert depth (D) ratio was greater than 1.7 or if the calculated HW overtopped the roadway.

The recommended alternative will include several drainage improvements as follows:

- Hydraulic calculations show about 1/4 of the culverts analyzed along this portion of I-40 have insufficient capacity to pass the estimated peak 50-year discharge. These culverts either require upsizing or addition of barrels to satisfy ADOT standards for highway cross culverts.
- The widening of the roadway prism to accommodate additional lanes will require extension of the existing culverts. Proposed culvert extension hydraulic calculations that were performed as part of the *Preliminary Drainage Report* are preliminary in nature.

The *Preliminary Drainage Report* documents performance of the large and special culverts. The remaining culverts will likely require extension as part of the widening of I-17, and may require performance evaluations as well during the final design stage.

The final designer should review the need for energy dissipators at culvert outlets to mitigate erosion or the potential for erosion at culvert outlets.

4.7 Floodplain

Within the project limits, I-40 crosses or parallels several designated FEMA flood zones as shown on current FIRM. The following table indicates the existing FEMA designated flood zones as shown on the FIRM along the I-40 corridor.

Table 52 – FEMA Floodplain Delineation

FIRM PANEL NUMBER	WASH OR CREEK	LOCATION	FEMA FLOOD DESIGNATION
040020 0011 B	Volunteer Wash	MP 195.3	Zone A, Zone A4, Zone B
040020 0011 B	Sinclair Wash	MP 195.3	Zone A, Zone A4, Zone B
040020 0012 B 040020 0008 B 040020 0004 C	Rio de Flag	Multiple crossings	Zone A, Zone A5, Zone A15, Zone B
040020 0007 D	Switzer Canyon Wash	MP 198.9	Zone A2
040020 0008 B	Spruce Avenue Wash	MP 199.0	Zone A
040020 0003 C	Fanning Drive Wash	MP 200.4	Zone A1
040020 0004 C	Penstock Avenue Wash	MP 201.8	Zone A1
040019 3600 B	Wildcat Canyon Creek	MP 206.5	Zone A
040019 3600 B	Walnut Creek	MP 210.1	Zone A

The FEMA flood zones are defined as follows:

Zone A is defined as “no base flood elevations determined.”

Zones A1 - A30 are defined as “areas of 100-year flood; base flood elevations and flood hazard factors determined.”

Zone B is defined as “areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (medium shading)”

The remaining areas adjacent to I-40 are identified as Zone C. FEMA defines Zone C as “areas of minimal flooding. (no shading)”

The widening of I-40 will likely impact some of the flood zones along the corridor. A Conditional Letter of Map Revision and a Letter of Map Revision (CLOMR/LOMR) may be required at these locations during final design. The CLOMR/LOMR will entail a detailed hydraulic analysis to show that I-40 widening improvements do not adversely impact flood zones that are adjacent to or cross the corridor.

4.8 Section 404 of the Clean Water Act

Coordination with the COE will be necessary during project design to ascertain the need for any nationwide or individual permits required under Section 404 of the Clean Water Act. Any deposition of fill material or excavation below the ordinary high water mark will require a permit. Once the need is determined, ADOT Environmental Planning Group will apply for all required permits. Construction activities that will require permits include, but are not limited to, bridge pier construction, culvert installations, replacements and/or extensions requiring excavation and placement of fill material, and roadway embankment widening.

Water resources include surface waters, potential wetland areas, and floodplains. Various drainages, including six named and 19 unnamed washes that may be potential waters of the United States, are located within the study area. Washes on the western portion of the study area flow generally south toward Sycamore Canyon, and washes on the central and eastern portions of the study area flow generally east or northeast toward the Colorado River.

Table 53 summarizes the crossings of potential jurisdictional washes within the study limits.

Table 53 – Corps of Engineers Jurisdictional Washes and Streams

WASH NO. & NAME	APPROXIMATE MP WASH CROSSES I-40	NOTES
Wash 1 (Unnamed)	185.9	Not within the vicinity of any proposed TI
Wash 2 (Volunteer Wash)	186.2	Not within the vicinity of any proposed TI
Wash 3 (Unnamed)	186.9	Not within the vicinity of any proposed TI
Wash 4 (Unnamed)	188.1	Not within the vicinity of any proposed TI
Wash 5 (Unnamed)	N/A	Located generally parallel to I-40 between approximately MP 188.4 and MP 189.5
Wash 6 (Unnamed)	190.9	Within the vicinity of the A-1 Mountain TI; this wash curves to the east and also approaches approximate MP 192.7 within the vicinity of the Flagstaff Ranch TI
Wash 7 (Unnamed)	N/A	Does not appear to cross I-40, but is located near MP 192.5; within the vicinity of the Flagstaff Ranch TI
Wash 8 (Unnamed)	194.1	Not within the vicinity of any proposed TI
Wash 9 (Sinclair Wash)	195.2	Within the vicinity of the I-40/I-17 system TI
Wash 10 (Unnamed)	N/A	Does not appear to cross I-40, but is located near MP 195.3; within the vicinity of the I-40/I-17 system TI
Wash 11 (Unnamed)	N/A	Located generally parallel to I-40 between approximately MP 195.8 and MP 197.4; within the vicinity of the Lone Tree Road TI
Wash 12 (Rio de Flag)	197.4, 201.9	Crosses I-40 at two locations; within the vicinity of the Country Club TI and new US 89 TI
Wash 13 (Unnamed)	N/A	Does not appear to cross I-40, but is located near MP 197.5
Wash 14 (Unnamed)	198.9	Within the vicinity of the Butler TI
Wash 15 (Unnamed)	203.4	Not within the vicinity of any TI
Wash 16 (Unnamed)	204.3	Not within the vicinity of any TI
Wash 17 (Wildcat Canyon)	205.3	Within the vicinity of the Walnut Canyon TI
Wash 18 (Unnamed)	206.3	Not within the vicinity of any TI
Wash 19 (Unnamed)	207.6	Within the vicinity of the Cosnino TI
Wash 20 (Unnamed)	N/A	Does not appear to cross I-40, but is located near approximate MP 207.6, within the vicinity of the Cosnino TI
Wash 21 (Unnamed)	208.6	Not within the vicinity of any TI
Wash 22 (Walnut Creek)	210.3	Not within the vicinity of any TI
Wash 23 (Unnamed)	210.5	Not within the vicinity of any TI
Wash 24 (Young Canyon)	213.1	Not within the vicinity of any TI
Wash 25 (Unnamed)	213.7	Not within the vicinity of any TI

Potential washes and their locations are based on Arizona State Land Department, Arizona Land Resources Information System. 1993. *Ephemeral and Perennial Streams in Arizona*. No jurisdictional delineation or associated field survey has been conducted, and the jurisdictional status of these washes has not been determined. Additional washes not listed may also be determined as jurisdictional during the jurisdictional delineation for this project.

4.9 Geotechnical

4.9.1 General Geologic Conditions

It is anticipated that embankment fills will be constructed using available materials from nearby rock cuts. In general, the geologic materials exposed will be suitable for embankment and ramp fills. Cut slope ratios and performance will vary considerably from one rock type to another.

Due to the length of the project and the variations of materials located within the project limits, it is impracticable to correlate specific earthwork factor estimates with specific rock unit locations with precision. Additionally, shrink/swell results are highly dependent upon procedures used by the contractor.

4.9.2 Preliminary Cut Slope Recommendations

The ADOT RDG includes several statements regarding the design of side slopes in Section 303.3 as follows:

> Cut and fill slopes should initially be designed as shown in the C-02 series of the Construction Standard Drawings. Final slopes are then incorporated into the design and shown on the plans as required by the Project Geotechnical Report, Materials Design Report, and other considerations such as slope flattening for elimination of barrier, cut widening to facilitate drainage, rockfall, landscape and vegetation establishment, and visual mitigation.

Although this is a preliminary design project, an attempt was made to predict potential modifications to the slopes based on the considerations cited above to estimate the potential impacts those modifications may have on R/W needs and construction cost.

In general, rock cuts in volcanic rock such as un-weathered basalt and andesite can be excavated at a rate no steeper than ¾:1 (H:V). In highly weathered and heavily jointed volcanic rock such as basalt, andesite and cinders, excavation slopes should be considerably flatter, ranging from 1:1 to 3:1 depending on local conditions. In sedimentary materials, competent un-weathered material can be excavated at a rate no steeper than ¾:1. However, weathered and fractured sedimentary materials and limestone that contain solution features will also need to be constructed at considerably flatter slopes ranging from 1:1 to 3:1.

Rock cut slopes and excavations in excess of 20 feet in height will need further geotechnical evaluation for final project design.

The cut slope ratios presented above are considered maximum slope ratios and flatter slopes will tend to be more stable. Higher cuts will require rockfall containment ditches matched to the slope ratio and height. Rockfall containment criteria were developed for the project based on exposed rock and cut slope angle. These criteria are included in the *Geotechnical Assessment* and a brief summary is shown in Table 54. Figure 48 illustrates the rockfall containment ditch criteria.

Table 54 – Rockfall Containment Ditch Design Criteria

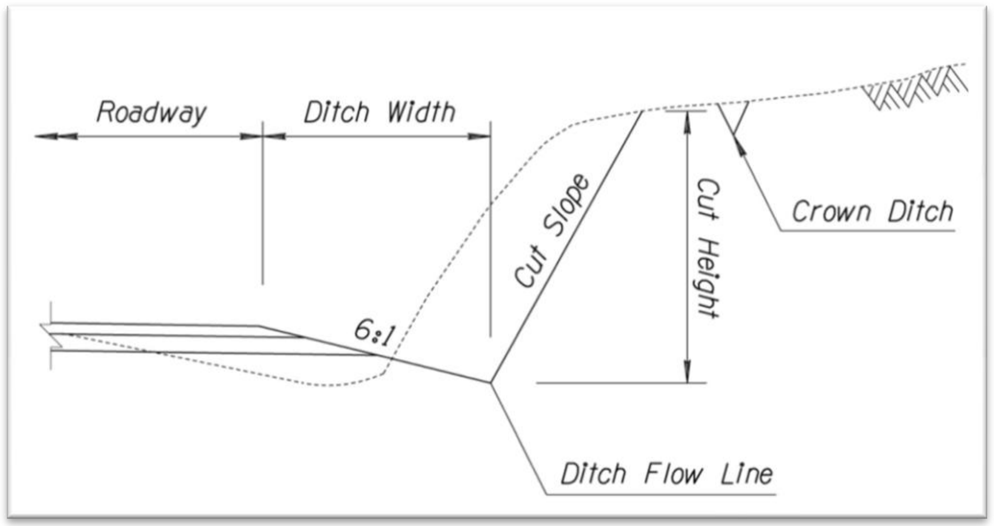
CUT HEIGHT	CUT SLOPE (H:V)	DITCH WIDTH (6:1)
Less than 40 feet	1:1	25 feet
	0.75:1	15 feet
40-60 feet	1:1	28 feet
	0.75:1	30 feet
60-80 feet	1:1	40 feet
	0.75:1	37 feet

Protective measures, such as rock catch fences or draped mesh, may be required at certain locations. Crown ditches are recommended on the top of proposed rock cuts that have an exposed height of greater than 40 feet. Crown ditches should be located sufficiently away from the cut slope face to provide stability of the remaining rock unit.

Preliminary Rockfall Containment: Three known rockfall locations were identified for specific discussion:

- Mainline – Sta. 1800+00 to Sta. 1846+00 (MP 188.46 to MP 189.33) – The westbound roadway would be lowered to flatten the grade through this segment of I-40. To address the rockfall containment issues along the north side of the roadway, a four-foot deep ditch is recommended 33 feet from the new edge of pavement. The cut slope is shown at 3:1. The slope is very conservative and would likely be steepened in final design to a range of ¾:1 to 2:1. Slope stability is the controlling issue, more than the rock containment ditch depth and width. ADOT Materials recommended a 30-foot maximum width from the edge of pavement to catch point for areas that require rockfall containment mitigation. Potential visual concerns for these locations will be evaluated in the Draft EA. Slope stabilization measures could compromise the aesthetics.
- A-1 Mountain Westbound Exit Ramp – Sta. 1919+00 to Sta. 1925+00 (MP 190.71 to MP 190.83) – The railroad structures to the immediate east are recommended for replacement and the recommended mainline geometrics will flatten horizontal curves, improve superevelation, and lengthen vertical curves in this general location. These proposed improvements will affect the existing cut section north of the westbound roadway. Different cut slopes would affect the amount of cut required and the impact to the existing 69 kV overhead power line that exists on top of the slope.
- Fourth Street Vicinity – Sta. 117+00 to Sta. 120+00 (MP 199.1 to MP 200.4) – It is recommended that the mainline roadways be shifted toward the median in this section to limit impacts to the existing outside rock cuts in the vicinity of the Fourth Street crossing. A new rockfall containment ditch would be constructed at the bottom of the existing 1:1 rock cut slopes. ADOT Materials Group recommended removing the steeper 3:1 slope section of the roadway side of the ditch, and extending the 6:1 slope to the bottom of the ditch. Reducing the width of the ditch to 25 feet based on the height of the cut slope is also recommended. This width will still provide sufficient room for snow storage during snow removal operations. Some of the rock outcropping in the median will be preserved if possible. The new bridge at Fourth Street will require barrier protection in the median.

Figure 48 – Rockfall Containment Ditch Layout



Slope rounding is recommended per the C-02 Construction Standard Drawings in cuts that are not in solid rock. The *Geotechnical Assessment* recommends that cut slopes be flattened to a slope ratio of 1.5:1 and rounded to blend with the surrounding landscape. This rounding should be performed in the upper twelve feet of the cut and should minimize the dislodging of loose debris from the crests of slopes where an upper weathered profile of rock may be present.

The plan sheets in the appendices show the catch point of the cut slopes but do not reflect additional impacts from slope rounding or crown ditches.

Rockfall Areas

There are six identified rockfall sites within the project limits as listed in Section 1.5.7 of this report. The following table lists the location and proposed work to mitigate the rockfall issues.

Table 55 – Rockfall Mitigation Areas

MP		WB/EB	LOCATION DESCRIPTION	PROPOSED WORK
START	END			
188.9	188.5	WB	S-curve realignment section	Widen and deepen ditch; lay back slope
189.5	189.2	WB	S-curve realignment section	Widen and deepen ditch; lay back slope
190.9	190.7	WB	WB exit ramp at A-1 Mountain TI	Widen and deepen ditch; lay back slope
199.1	199.4	EB	Cut section at Fourth Street	Widen and deepen ditch
199.4	199.1	WB	Cut section at Fourth Street	Widen and deepen ditch
202.0	202.2	EB	EB exit ramp at new US 89 TI	Widen and deepen ditch

4.9.3 Preliminary Fill Slope Recommendations

Embankment slopes that are less than 10 feet and which utilize local materials can generally be constructed in conformance with the ADOT standard construction drawings. The preliminary recommended maximum fill slope rate is 2:1. Much of the native soil that has been utilized as embankment material on the bottom and outer sides of the existing highway fills may be clayey and contain oversized materials. As such, they may not provide a suitable subgrade immediately below the pavement structural section of the proposed new lanes. These areas may need to be over-excavated.

Slope flattening for vegetation establishment or aesthetics has not been included in the preliminary design.

4.9.4 Bridge and Wall Support Systems

The corridor is primarily underlain by a bedrock environment but includes a variety of rock types. Foundation conditions generally will be good for support of roadways and bridges. Typically the upper 5-10 feet of rock materials should be considered weathered and deteriorated. Existing structures within the project corridor have utilized outcrops of the Kaibab Formation, Moenkopi Formation and volcanic basalt as a bearing stratum and bridge foundations can vary from shallow spread footings to rock socketed drilled shafts and driven piles. The USGS has reported the presence of perched ground water conditions within the project corridor and the potential impacts on foundations will need to be addressed further during final design.

4.10 Earthwork

4.10.1 Preliminary Earthwork Factors

The estimated earthwork factors for the geologic units within the project corridor are shown in Table 56.

Table 56 – Estimated Earthwork Factors

MP RANGE	GEOLOGIC UNIT	EARTHWORK FACTOR	GROUND COMPACTION
183.0 - 194.5 197.7 - 199.1 201.0 - 201.9 210.4 - 211.9	Volcanic Rocks consisting of: Basalt Flows Andesite Flows Cinders Tuffs	 15- 20% swell 10 - 15% swell 0 - 5% shrink 5 - 10% shrink	 0.0’ 0.0’ 0.0’ - 0.2’ 0.0’ - 0.2’
195.2 - 197.7 199.1 - 201.0 201.9 - 210.4 212.0 - 214.0 211.9 - 214.0	Sedimentary Rocks consisting of: Kaibab Formation Limestone/Sandstone Harrisburg Member Fossil Mountain Member	 10 - 15% swell 10 - 15% swell 10 - 15% swell	 0.0’ 0.0’ 0.0’
183.0 - 214.0	Existing Compacted Rock Fill	Even	0.0’
183.0 - 214.0	Existing Compacted Soil Embankment	Even	0.0’ - 0.1’
183.0 - 214.0	Native Soil	0 - 10% shrink	0.2’

4.10.2 Earthwork Summary

An earthwork estimate has been developed for the Recommended Alternative and is shown in Table 57. The end-area method was used with sections cut at a minimum interval of 100 feet. As indicated by the precision shown, the estimates are approximate and reflect a level of detail commensurate with the concept study

Table 57 – Earthwork Summary

MP	EXCAVATION (CU. YDS.)	EMBANKMENT (CU. YDS.)	BALANCE (CU. YDS.)
183.0 - 214.0	2,559,000	3,265,000	(707,000)

Although the corridor-wide earthwork estimate anticipates the need for borrow, construction phasing operations, implementation order of project segments, and the possibility of encountering material that is unsuitable for use in embankments may dictate the need for a waste location.

4.10.3 Potential Borrow Sources

ADOT Materials Group does not designate borrow source for individual projects. There are five commercial borrow sources in the region that may be able to supplement part of the resources necessary to construct the proposed improvements associated with this corridor study (Table 58). However, the need for a large free-use materials source should be investigated to offset cost of obtaining limited commercially available construction materials at a competitive price.

Table 58 – Commercial Pit Summary

OWNER	NAME	LOCATION	AVAILABLE MATERIALS					
			MINERAL AGGREGATE	AGGEGRATE BASE	SAND	RIPRAP	BORROW	CINDERS
Flagstaff Cinder Sales	Wildcat Pit	Adjacent to I-40 MP 204				X	X	X
Luepp Materials Source	Luepp Pit	14 miles NE of Flagstaff on Luepp Rd				X	X	
Miller Mining Inc.		20 miles East of Flagstaff on US 89		X	X		X	
United Metro	Robinson Crater	1 mile east of US 89 MP 432	X	X	X	X	X	
United Metro/ Rinker	Gray Mountain	34 miles north of Flagstaff, US 89 MP 455	X	X	X	X	X	

4.11 Constructability and Traffic Control

Existing vehicle movements and highway access must be maintained during construction. Because there are limited alternate routes, closure of I-40 will not be allowed other than for short periods of time. Final construction sequencing/phasing will be determined during final design. Traffic will be managed using detailed traffic control plans and by procedures and guidelines specified in the *Manual on Uniform Traffic Control Devices*, 2003 Edition, and the 2003 ADOT *Traffic Control Design Guidelines*.

Major construction activities that disrupt traffic are to be performed during off-peak hours. Efforts to minimize the duration of construction should be made during final design. Existing movements and access to and from ramps must be maintained during construction. Other methods of reducing traffic impacts during construction, such as phasing the improvements so the entire length of the project is not under construction at one time, will be evaluated during the final design phase of the project.

Outside of major realignment areas, construction for the recommended improvements generally can be accomplished in two phases. The first phase includes construction/widening to the inside of the highway. To maintain traffic during this phase of construction, the width of the outside shoulder may be reduced. Temporary concrete barrier may be needed to protect the work area from freeway traffic. Once the new width is available, the second phase of construction will shift traffic to the newly-constructed inside lanes and off the existing lanes in order to improve the superelevation rates and transition runoff lengths.

In the locations of total reconstruction of bridges and major alignment improvements, "cross-over" construction phasing is recommended. This type of construction was recently used in the re-profiling project for westbound I-40 from MP 205 to MP 209. The westbound traffic was shifted over to the existing eastbound alignment. Westbound and eastbound traffic were reduced to one lane each direction. The removal of traffic on westbound allowed for major modifications to the existing roadway geometry in a shorter duration while limiting the impacts to the existing traffic operations.

Access to adjacent properties will be maintained during construction.

Funding is expected to be limited; construction of the improvements will likely occur in phases. An implementation plan to be developed in a later phase of the study will provide additional detail on constructability.

4.12 Traffic Interchanges

4.12.1 Introduction

Most of the recommended mainline widening is to the inside, thus limiting the need to shift ramps at interchanges. Most ramps throughout the project are part of diamond interchanges. The following section describes general elements of the widening at interchanges and provides additional details of the recommended alternative at each interchange.

The mainline will be widened by 26 feet to the inside through most interchanges. The proposed mainline improvements would consist of sawcutting the inside 4 feet of pavement and removing the existing inside shoulder. The new 26 feet of pavement added to the inside would provide additional inside shoulder width (total of 12 feet), an additional travel lane (12 feet), and the additional outside shoulder width (2 feet). This provides a total three-lane roadway width of 60 feet.

Reconstruction of interchange ramps should comply with design guidelines for side slopes, horizontal geometry, vertical geometry, and improved traffic operations. Some ramps will require total reconstruction while others will need only minimal reconstruction.

The existing taper-type ramps will be converted to parallel-type ramps or the taper length will be extended from a 50:1 taper to 60:1 taper at recommended locations to provide additional length for drivers to merge with or diverge from mainline traffic. See Section 4.12.16, Ramp Type Recommendations, for additional information.

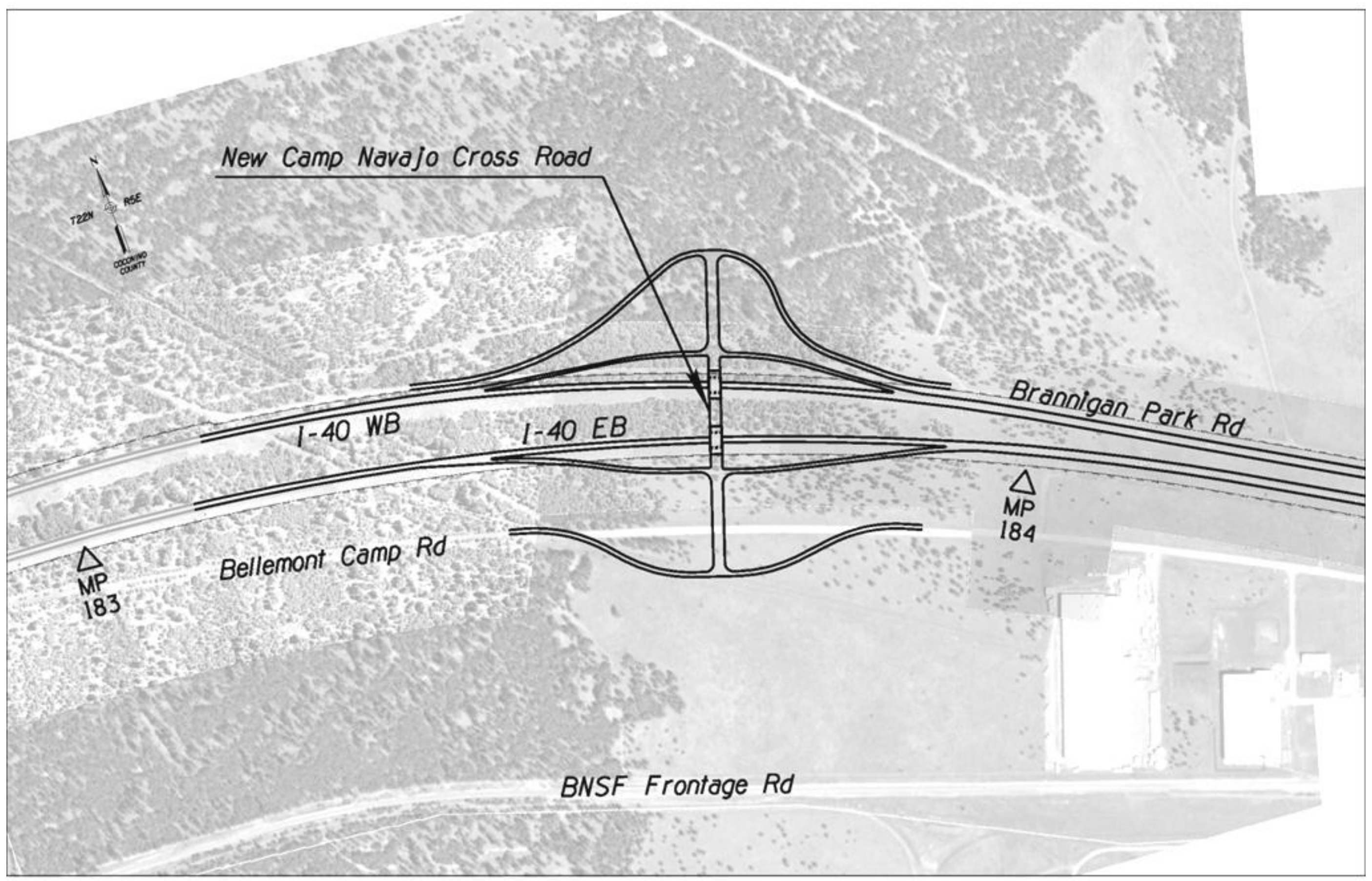
4.12.2 New Camp Navajo TI

Planned development at the eastern end of the study area warrants a new traffic interchange west of the existing Bellemont TI. The new Camp Navajo TI will be located at approximately MP 183.66. This interchange will provide a second access to I-40 from the Camp Navajo Army Depot and planned industrial development to the south. The new interchange will relieve some of the existing operational issues at the Bellemont TI (MP 185.15).

The new interchange will have a diamond configuration, with the cross road above eastbound and westbound I-40. The eastbound and westbound mainlines are separated by a varying 200-300 foot wide naturally vegetated median. The posted speed in this area is 75 mph. The terrain is considered level to rolling with an average elevation of 7180 feet.

The proposed eastbound exit and westbound entrance ramps are taper-type ramps. The proposed eastbound entrance ramp will add the third outside lane as it connects to the mainline in a parallel-type ramp configuration. The proposed westbound exit ramp will drop the third outside lane. The entrance and exit ramp widths are 22 feet and consist of a 12-foot lane, 2-foot inside shoulder and an eight-foot outside shoulder. The ramps widen at the intersections with the cross road to provide left and right turn lanes. The ramp intersections are spaced 775 feet apart. Roadway ramp gore lighting is proposed.

Figure 49 – New Camp Navajo TI



The proposed cross road will be 76 feet wide and consists of a 12-foot median and two 12-foot through lanes and an 8-foot shoulder in each direction. The cross road is on a horizontal tangent perpendicular to the I-40 mainline alignments to reduce structure length and limit skews of the ramp intersections. Both of the proposed structures are located on a 600-foot vertical curve. The approach grades are 4.0% from the south and 4.0% from the north.

The proposed interchange will realign the frontage roads which parallel the interstate on the north and south sides. The proposed intersections at the cross road and the frontage roads are 660 feet from the ramp intersections. The north frontage road, Brannigan Park Road, is a 22-foot wide two-way roadway. The south frontage road, Bellemont Camp Road, is a 22-foot wide two-way roadway. Both frontage roads are located outside the ADOT R/W and are under the jurisdiction of Coconino County.

The eastbound exit ramp will have a maximum profile grade of +2.0% and the eastbound entrance ramp will have a maximum profile grade of -2.56%. The westbound exit ramp has a maximum profile grade of +4.0% and the westbound entrance ramp has a maximum profile grade of -2.2%. The ramp grades are described in the direction of travel.

These proposed improvements will require 41.5 acres of new R/W.

4.12.3 Bellemont TI

As discussed in Section 3.4.2, the realigned diamond configuration of the Bellemont TI will shift the cross road approximately 800 feet to the east. The frontage road to the south will need to be raised to connect the railroad bridge to the south and the new interchange structures to the north. The existing access road to the BNSF railroad will be reconstructed to the east of its current location because of embankment impacts from the realigned cross road.

The ramp intersections with the cross road will remain approximately 600 feet apart. The intersections will be two-lane roundabouts. The intersection of the new cross road and the county road to the north, Shadow Mountain Lane, will be approximately 560 feet north of the westbound ramp intersection. Re-aligning the cross road to the east not only improves intersection separation distance between the ramp intersections and the adjacent north frontage road, but it relocates the new intersection 660 feet from the entrance of the truck stop to the east. The increased separation between the truck stop and the TI should improve operations at the interchange. The intersection of the north frontage road and the cross road will be a one-lane roundabout. The new intersection between the realigned cross road and the south frontage road, Bellemont Camp Road, will remain approximately 300 feet south of the ramp intersection. The south frontage road will be stop-controlled, allowing the cross road traffic the through movement.

If Camp Navajo identifies the need to widen the existing two-lane railroad crossing structure south of the interchange, a fourth roundabout intersection should be considered to maintain consistency and acceptable operational levels at the Bellemont TI.

The maximum grade on the cross road south of the ramps is 3%; the maximum grade on the south frontage road (Bellemont Camp Road) will be 5%. The new cross road structure over I-40 will be within a 500-foot vertical curve, with an approach grade of 3.0% from the north and 1.9 % to the south to match the railroad structure.

The eastbound exit ramp has a maximum profile grade of +4.3% and the eastbound entrance ramp has a maximum profile grade of -3.0%. The westbound exit ramp has a maximum profile grade of +1.7% and the westbound entrance ramp has a maximum profile grade of -2.4%. The ramp grades are described in the direction of travel.

The profile grade of the south frontage road will require modification to intersect the realigned cross road. Approximately 2300 feet of the south frontage road will be reconstructed to raise the profile 19 feet.

The approximate R/W required for this alternative is 19.3 acres.

4.12.4 A-1 Mountain TI

The A-1 Mountain TI is a diamond interchange with the cross road over I-40 and with ramp/cross road intersections spaced approximately 540 feet apart. The close intersection spacing results in ramps that are in close proximity to the mainline with steep side slopes between the mainline and ramps. The mainline will be realigned through this interchange to improve the geometrics at the adjacent new BNSF railroad structures. The mainline profiles will be lowered approximately two feet at the cross road structures to provide the required vertical stopping distance and vertical clearance. This mainline profile and horizontal adjustment will require that the ramps on the east side of the interchange be reconstructed.

The existing eastbound entrance ramp will be lengthened onto the new eastbound BNSF structure, providing a standard taper-type ramp. The westbound exit ramp will be slightly modified to tie into the realigned westbound mainline. The westbound exit ramp cuts into an existing hillside which is a recommended rockfall mitigation area. The rockfall hazard will be mitigated by cutting a flatter slope into the hillside and providing a wider containment ditch on the outside of the exit ramp.

Other proposed improvements will include lengthening the vertical curves on the western ramps to improve the vertical stopping sight distance. These modifications will require reconstruction of most of the ramp lengths. The eastbound exit ramp vertical curve length will increase from 400 feet to 700 feet. The westbound entrance ramp vertical curve length will also increase from 400 feet to 700 feet. Current design criteria for the ramp vertical alignment (grade, stopping sight distance) will be satisfied by the modified ramp geometry.

Approximately five acres of new R/W are required at this interchange for ramp reconfiguration and for the rockfall mitigation along the westbound exit ramp.

4.12.5 West Flagstaff TI

The West Flagstaff TI is located at MP 191.69. This interchange is the westernmost I-40 interchange that provides access to Flagstaff. Business Loop 40/Old US 66 can be accessed at this interchange.

The existing trumpet interchange configuration will not be modified. The proposed mainline improvements within the limits of the interchange include raising the profiles of the eastbound and westbound roadways over the existing cross road. Both overpass structures will be replaced with a new wider and deeper structure. The structure will accommodate not only the additional width required for the three-lane section, but also new parallel ramps for the eastbound entrance and westbound exit movements.

The proposed improvements for this interchange include the re-profiling of all the ramps at the gore locations to match the raised mainline profiles. Slight adjustments will be made to the horizontal alignments to improve the horizontal curvature and superelevation to current design standards.

A total of 1.2 acres of new R/W is required along the westbound entrance ramp for these improvements.

4.12.6 Flagstaff Ranch TI

The existing Flagstaff Ranch TI is a diamond interchange located at MP 192.56. The existing cross road provides access to residential developments to the south and access to Business 40 to the north. The ramp/cross road intersections are spaced approximately 550 feet apart. The mainline alignment is tangent with horizontal curves at the ramp gores east of the interchange. The terrain slopes downward to the east.

Only ramp gore modifications are proposed for this interchange. The eastbound entrance ramp and westbound exit ramp will be converted from taper-type ramps to parallel-type ramps with an auxiliary lane connecting to the new Woody Mountain TI ramps. The auxiliary lanes are required because the termini of the Flagstaff Ranch TI eastern ramps are very close to the ends of the new Woody Mountain TI western ramps.

The mainline structures are relatively new and will be widened over the cross road. The vertical clearance on the cross road will not meet the desired 16.5 feet. A design exception will be requested since lowering the profile of the cross road would require total reconstruction of the road between the ramp intersections and would potentially impact underground utilities.

No additional R/W is required for the improvements at this location.

4.12.7 New Woody Mountain TI

The existing Woody Mountain overpass structures do not provide the required horizontal and vertical clearances to accommodate the widened mainline cross section (60 feet each direction). Two alternatives were developed to provide new access to I-40 at this location as discussed in Section 3.5.2.

The recommended roundabout alternative will provide standard roundabouts at the ramp/cross road intersections. Right-in/right-out movements will be provided at the intersection closest to the interchange (Presidio Drive) and a third roundabout at the Patio del Presidio intersection farther to the north.

The existing approach grades on Woody Mountain Road are steep. The I-40 mainline profile will be lowered and the cross road profile flattened to accommodate added structure depth and provide desirable intersection approach grades on the cross road. The mainline roadways will be shifted toward the median to reduce potential R/W impacts.

The proposed improvements will require 11.2 acres of new R/W.

4.12.8 I-40/I-17 System Interchange

I-40 crosses over I-17 at MP 195.5. The interchange is the northern terminus of I-17. The system interchange was reconstructed in 2000. The reconfiguration consisted of the conversion from a cloverleaf interchange to an interchange with more direct ramp movements and improved loop ramp radii.

The proposed modifications at the system interchange result from the recommended widening of the eastbound and westbound mainlines. The additional lanes in each direction, as well as the conversion of taper-type entrance ramps to parallel-type ramps, require replacement of four I-40 mainline structures as discussed in the Structures section later in this chapter. The existing mainline pavement will be removed and replaced with dowelled PCCP.

4.12.9 New Lone Tree TI

A recommended alternative has not been identified for the new Lone Tree TI. The Braided Over and the Braided Under alternatives are recommended for further consideration.

Both alternatives would connect I-40 to a new Lone Tree Road alignment approximately 1300 east of the existing Lone Tree Road grade separation. The Braided Over and Braided Under alternatives provide a braided ramp configuration for the westbound I-40 to southbound I-17/Milton Road system interchange ramp. The braided concept eliminates mainline weaving by shifting all entering and exiting traffic to a parallel C-D road. The C-D road is a separate, long exit ramp for traffic destined for southbound I-17 or Milton Road. It also includes westbound new Lone Tree TI traffic destined for either the I-17/Milton ramp or to westbound I-40. For both the Braided Over and Braided Under alternatives, the LOS for the westbound system ramp weave would be LOS C and the westbound I-40 mainline would be LOS B.

Approximately one mile of westbound I-40 will need to be reconstructed in the median area. The existing westbound I-40 bridge over Lone Tree Road will need to be replaced to accommodate the shifted horizontal alignment and raised mainline profile. The existing eastbound bridge over Lone Tree will need to be widened to the inside; however, replacement of this bridge is also recommended. An additional bridge for the westbound braided ramp over or under the new Lone Tree TI westbound entrance ramp and retaining walls will be required.

The approximate R/W required for the new Lone Tree TI is 19.9 acres for the Braided Under Alternative and 18.9 acres for the Braided Over Alternative.

4.12.10 Butler TI

The Butler TI, located at MP 198.28, was constructed in 1988 as a diamond interchange. The cross road, Butler Avenue, crosses under the eastbound and westbound mainlines of I-40 at a 45° skew. This skew contributes to the 30° skewed exit ramp/cross road intersections, which is 15° greater than the recommend skew angle at intersections at the end of ramps.

Butler Avenue provides access to truck services immediately adjacent to I-40. Operational problems are caused by the large volume of trucks attempting to make 120° turns in the current ramp intersection configuration. The large angle makes it difficult for trucks to make the maneuver in a timely manner; therefore, fewer vehicles than desirable are able to pass through the intersection per signal cycle during peak times. This slow operation and a lack of storage on the existing exit ramps contribute to a queuing of traffic on the ramp. Separate ADOT studies considered possible solutions to help alleviate the congestion by widening the existing exit ramps at the intersections to provide dual left turns. Another solution was to reconfigure the signalized intersection to a roundabout design.

This study developed and evaluated four alternatives for this TI. As discussed in Section 3.4.3, it is recommended that the Roundabout, Signalized Diamond, and Double Crossover alternatives be carried forward for further evaluation and public input.

Depending on the preferred alternative, between 0.2 and 1.3 acres of new R/W would be required for the Butler TI.

4.12.11 Country Club TI

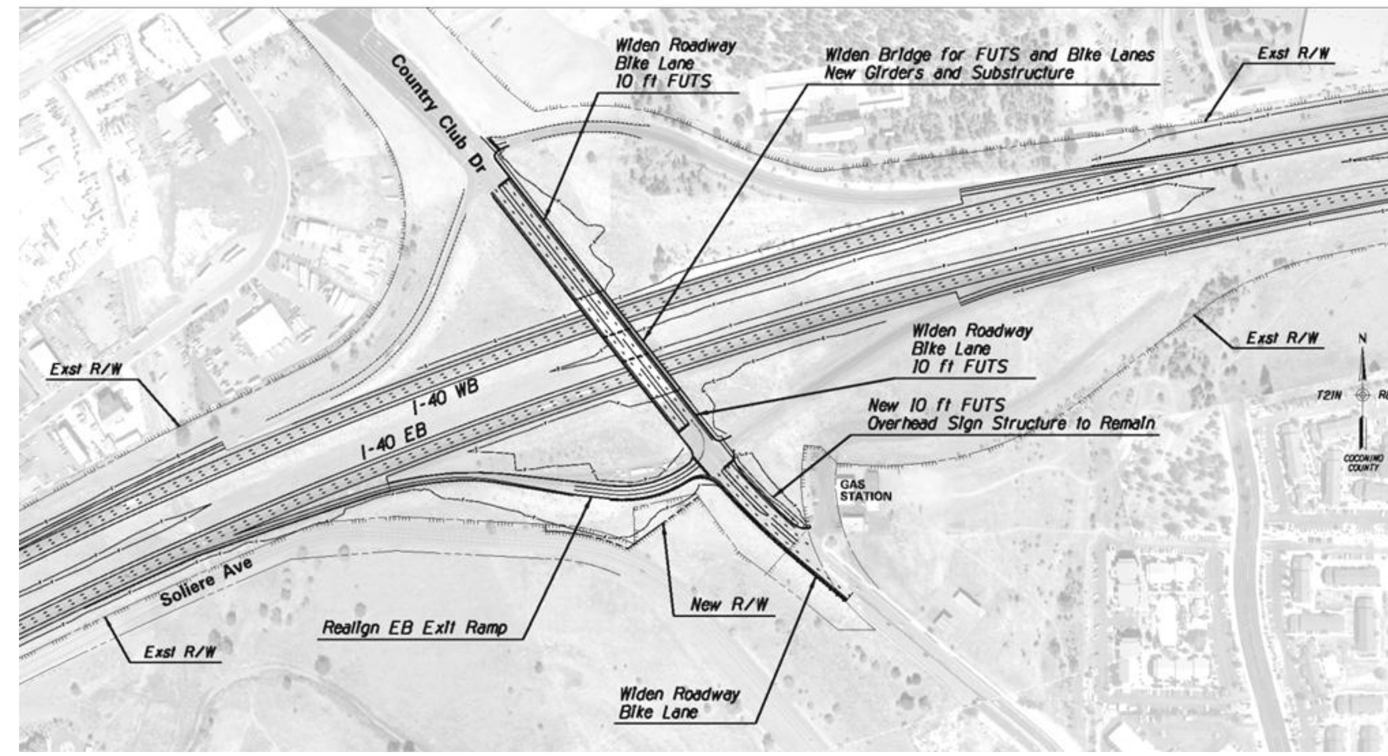
The Country Club Drive TI is located at MP 201.10. This interchange was reconfigured in 1989 per ADOT record drawings. The interchange is a diamond configuration with the cross road over eastbound and westbound I-40 on a two-span structure. Three of the existing ramps will remain in place; however, re-alignment and widening of the eastbound exit ramp is proposed to reduce the 26-degree skewed intersection angle and allow side-by-side truck turning movements from the eastbound ramp to northbound Country Club Drive.

In addition, widening of the cross road is recommended to provide five-foot wide bike lanes in both directions and a wider FUTS trail on the bridge. The existing bridge width is 78.0 feet. The proposed bridge width is 88.5 feet. The width would include 2-foot shy distances from the bridge barrier, 17-foot outside lanes, 12-foot inside lanes, a 12-foot turn lane, and a 10-foot FUTS trail. Barrier is located between the roadway and the FUTS trail.

The mainline within the interchange limits will be widened to three lanes in each direction within the existing median. The existing asphalt pavement will be replaced with a dowelled PCCP structural section. As part of the mainline reconstruction, the westbound profile will be lowered approximately six inches to provide the required vertical clearance at the Country Club underpass structure.

The proposed improvements will require 0.4 acres of additional R/W.

Figure 50 – Country Club TI



4.12.12 New US 89 TI

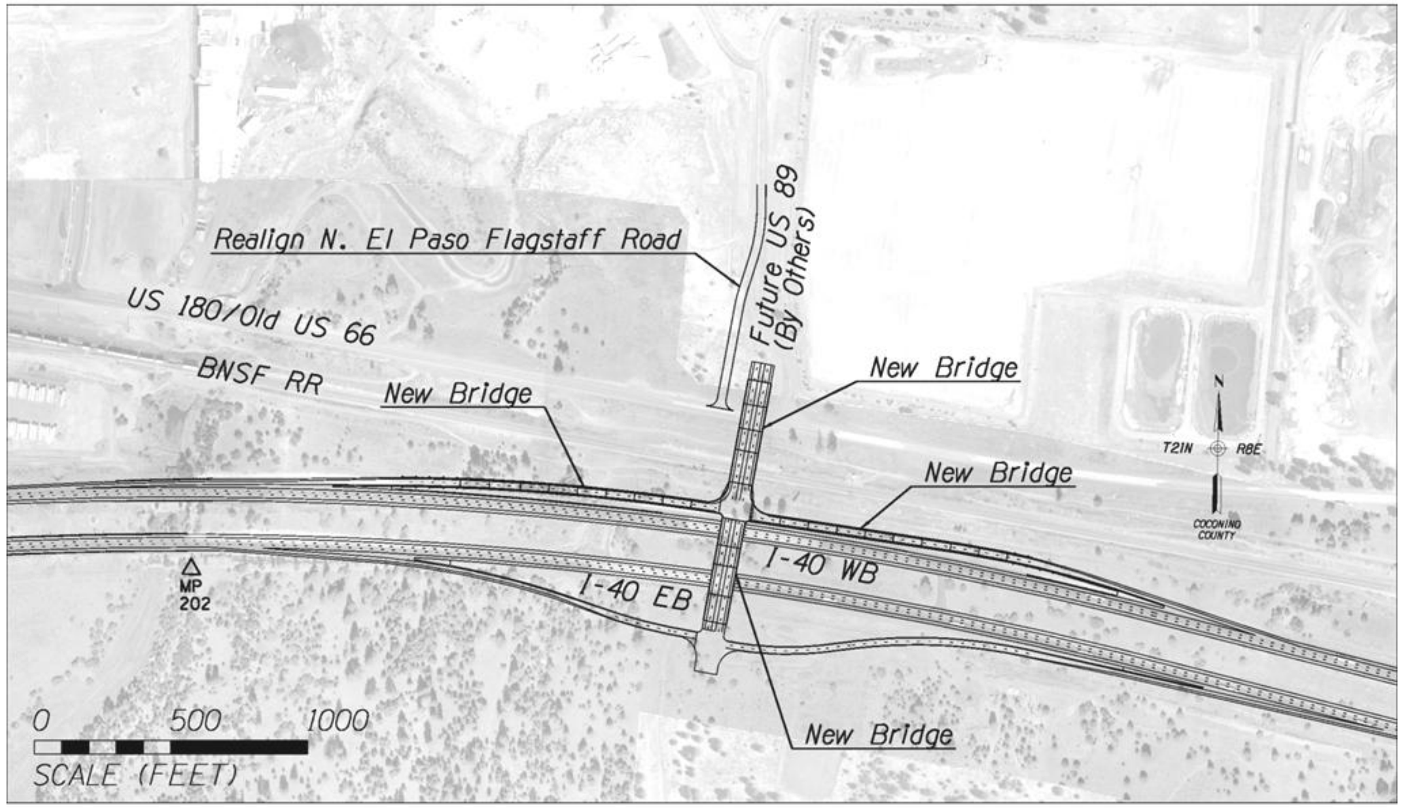
The new US 89 TI will be located in the vicinity of MP 202.31. This new interchange, combined with a new US 89 roadway by others, is proposed to relieve the current and future traffic on the segment of US 89 which runs through the developed areas of Flagstaff. The new traffic interchange would provide an additional access to and from I-40 east of the existing Country Club TI. It is envisioned that the new cross road will be extended north and west to connect with US 89 near the Townsend-Winona Road/US 89 intersection.

The proposed interchange is a tight diamond configuration. The westbound entrance and exit ramps are close to the mainline because of limited R/W and adjacent BNSF tracks. The cross road will cross above the eastbound and westbound mainline roadways, the two existing and potential future BNSF tracks, and Old US 66/US 180. The close proximity of the railroad to the new interchange and the vertical clearance requirements over the railroad require the westbound ramps to be constructed on structures adjacent to the westbound mainline. The use of retaining walls were considered in lieu of the structures for the ramps but were not developed further for reasons of cost, aesthetics, and additional drainage requirements.

The new interchange will impact existing overhead electrical lines at this location

The proposed improvements will require 20.4 acres of new R/W.

Figure 51 – New US 89 TI



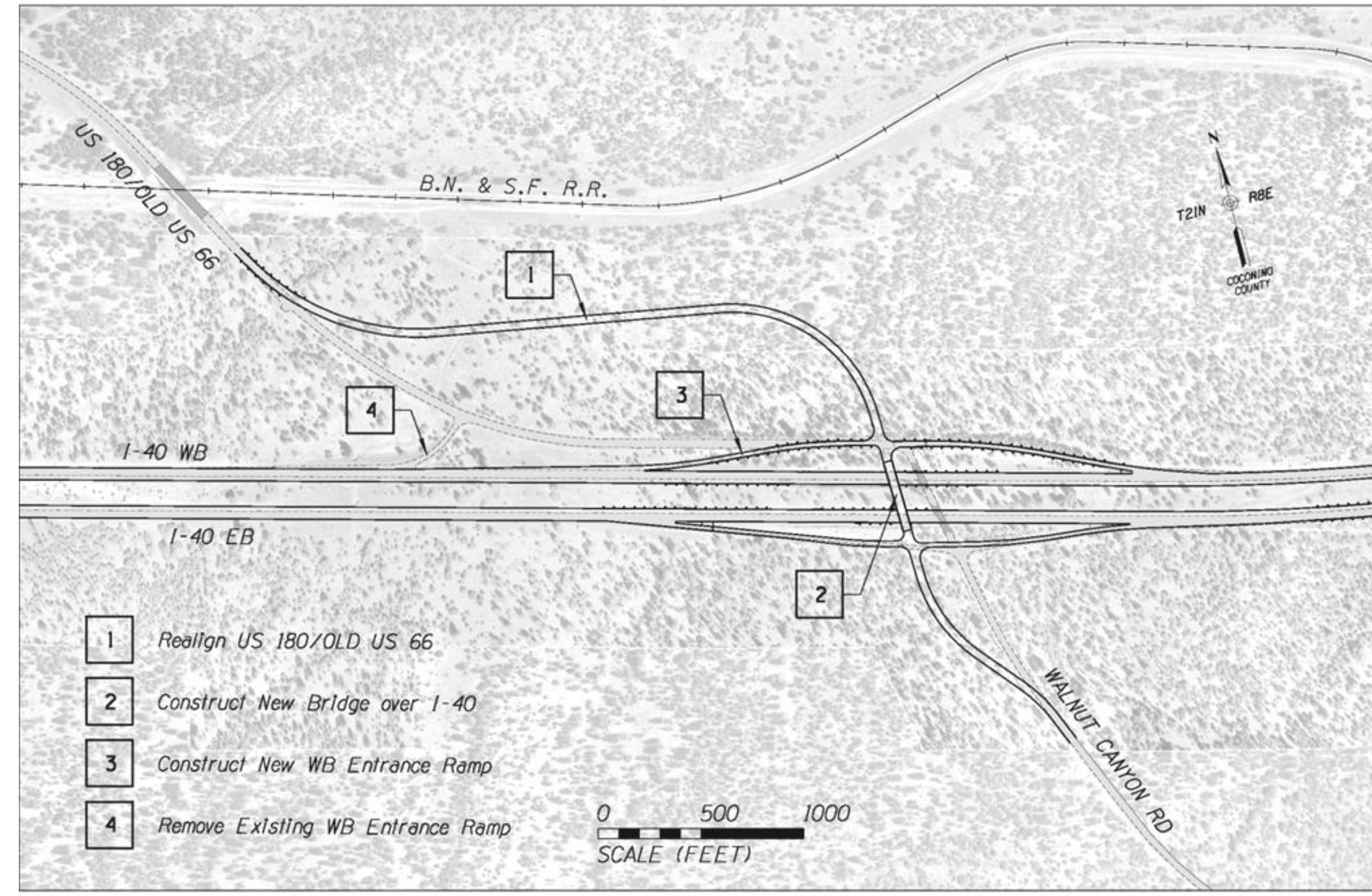
4.12.13 Walnut Canyon TI

The existing Walnut Canyon TI is located at MP 204.87. This interchange was originally constructed in 1966 and provides access to Walnut Canyon National Monument to the south and an alternate route to Flagstaff via Old US 66 to the north. The recommended alternative will reconstruct the two underpass structures to provide the necessary lateral and vertical clearances for the widened eastbound and westbound mainline roadways.

The proposed improvements at this location provide the opportunity to reconfigure one ramp of the existing configuration to resemble a more traditional diamond interchange configuration. The existing westbound entrance ramp is a short slip ramp located 2500 feet to the west of the cross road and the other three ramps. The new configuration would realign approximately 3600 feet of the cross road from the railroad crossing to the northern ramp/cross road intersection. The horizontal realignment will reduce the skew angle at the ramp intersections. The shifted cross road alignment will place the new structure approximately 80 feet west of the existing structure at the north end and 150 feet at the south end.

The new structure will be ten feet wider than the existing bridges. The new 40-foot roadway will provide a 12-foot lane and an 8-foot shoulder in each direction of travel. The structure will be within an 800-foot vertical curve, with an approach grade of 4.7% from the north and 2.9% from the south.

Figure 52 – Walnut Canyon TI Overview



The existing eastbound entrance and two exit ramps will be modified to tie into the realigned cross road. The modified eastbound exit ramp profile will steepen from a +3.6% to a +4.5% upgrade and lengthen the vertical curve from 400 feet to 600 feet to provide the recommended stopping sight distance. The reconstruction of this ramp also provides the opportunity to improve the superelevation. The eastbound entrance ramp horizontal alignment will be extended to the new ramp intersection with the cross road. The modified alignment will flatten the degree of curvature at the ramp's terminus and provide the recommended superelevation. The profile grade of this ramp will slightly reduce the existing grade from -4.3% to -4.0%.

The westbound exit ramp will be extended to intersect with the new cross road. The modifications will improve the curvature, superelevation and profile grade of this ramp. The new westbound entrance ramp will be constructed in a typical diamond configuration. This will improve the operations and be consistent with drivers' expectations at other interchanges throughout the I-40 corridor.

The improvements will require 14.5 acres of R/W for the realigned cross road. An additional 16.8 acres may be required between the realigned cross road and the existing I-40 R/W. For cost estimating purposes, the additional CNF property was not included in the total R/W.

4.12.14 Cosnino TI

The existing Cosnino interchange is a partial cloverleaf, with diamond ramps in the northwest, southwest, and southeast quadrants. The westbound exit ramp is a loop ramp in the northwest quadrant.

The Cosnino TI UP bridge is a 311-foot long, five-span steel girder bridge. The bridge is in good condition but has been classified as functionally obsolete due to vertical clearance. The westbound mainline lanes and the loop ramp deceleration lane are in Span 2; the eastbound lanes occupy Span 4.

The Recommended Alternative replaces the westbound loop exit ramp with a diagonal ramp and shifts the westbound entrance ramp to line up with the new diagonal exit ramp. The existing cross road structure would remain in place. The westbound mainline will be shifted 12 feet to the north and the profile lowered approximately one foot to accommodate the new 60-foot wide roadway between the existing spread footings.

The new diamond ramp requires substantial embankment material to cross the depressed terrain below. The amount of embankment is inversely related to the profile grade, with a steeper grade requiring less earthwork. For this alternative, a westbound exit ramp grade of 5% is recommended. Approximately 55,000 cubic yards of embankment material with fill heights of nearly 20 feet would be required.

A total of 3.1 acres of new R/W in the northeast quadrant is required for the new westbound exit ramp.

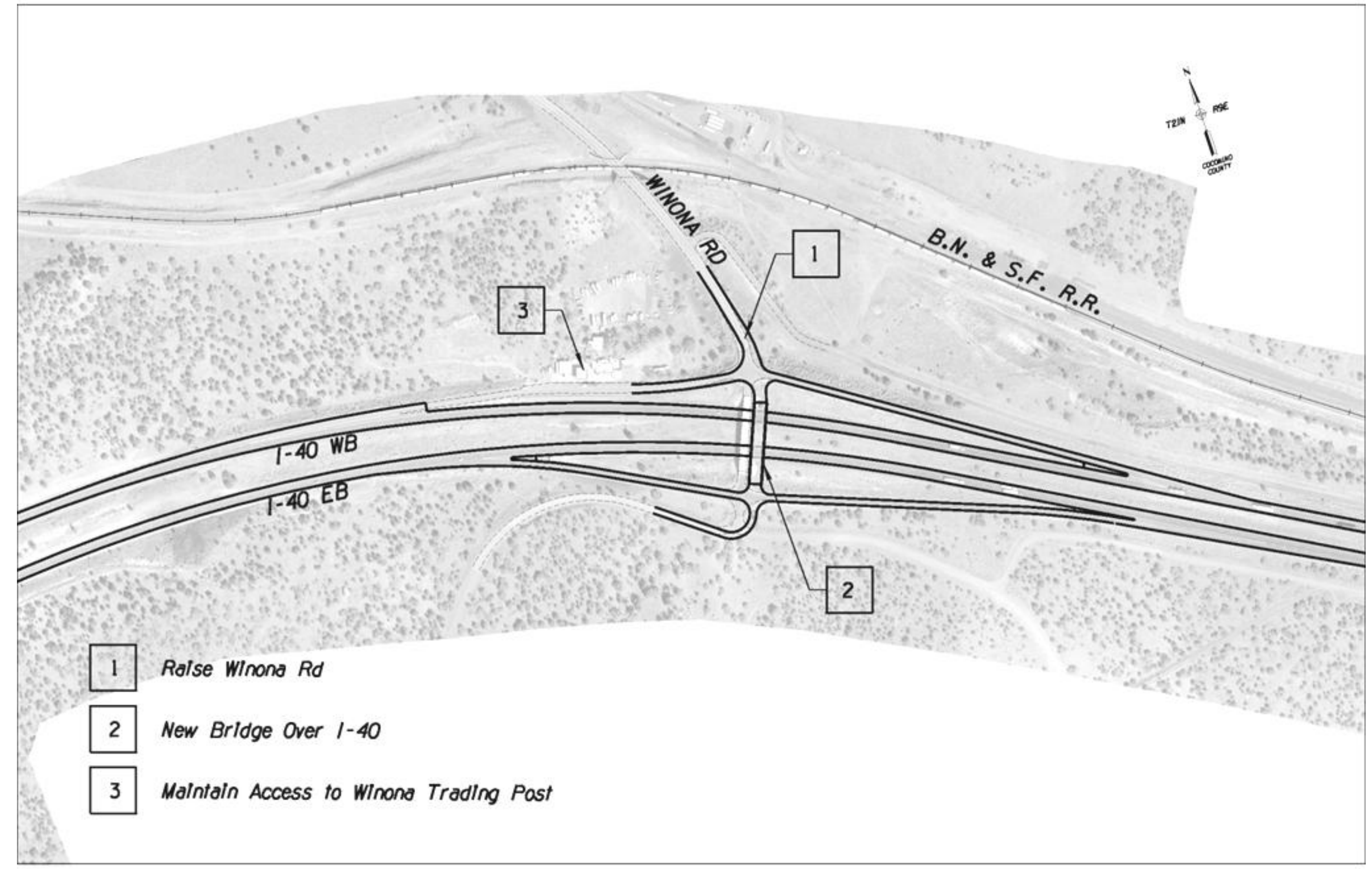
4.12.15 Winona TI

The Winona TI is located at MP 211.16. This interchange was originally constructed in 1967 and provides access to US 89 via Townsend-Winona Road to the north and a forest road and borrow pit road to the south. The recommended alternative will reconstruct the underpass structure to improve the horizontal and vertical clearances and provide the required load capacity necessary for the heavy truck volumes at this interchange.

The existing diamond configuration will remain with several major modifications. The cross road will be realigned 50 feet to the east as it crosses over I-40. This horizontal shift will allow construction of the new bridge while maintaining the use of the existing structure. The new structure will have fewer spans; thus, it will have a deeper structural depth. The profile of the cross road will be raised to accommodate the required vertical clearances for the existing two-lane eastbound and westbound I-40 roadways, as well as the addition of a future lane to the median in both directions. To limit impacts to the properties to the north and the intersection of Townsend-Winona Road and Old US 66, the profile grade of the cross road at the north approach was increased from +5.0% to +5.7%. The south approach of the cross road was increased from -1.5% to -1.7%. The new structure is within an 800-foot vertical curve. The cross road will be 44 feet wide between the ramp intersections to provide a 12-foot left-turn lane and a 12-foot lane with a 4-foot shoulder in each direction. North of the westbound ramp intersections, the cross road tapers to a 40-foot wide roadway, which provides a 12-foot lane and 8-foot shoulder in each direction.

The existing entrance and exit ramps will be modified to tie into the realigned cross road. The eastbound exit ramp will follow the existing horizontal alignment but extend to the new ramp intersection with the cross road. The profile of this ramp will steepen from +4.4% to +4.5% and the vertical curve will be lengthened from 400 feet to 700 feet to provide the recommended stopping sight distance. The reconstruction of the eastbound exit ramp also provides the opportunity to improve the superelevation. The eastbound entrance ramp will follow the existing horizontal alignment, but the superelevation will be improved from 1.5% to 5.0%. The downgrade will steepen from -4.9% to -5.4%.

Figure 53 – Winona TI



The horizontal alignment of the westbound exit ramp also will match the existing alignment. To intersect the raised cross road, the vertical profile of the ramp will remain at an approximate grade of +4.8% until leveling out at the new intersection location. The westbound entrance ramp will remain in its existing geometric configuration. However, the two-way frontage road which connects the ramp to the cross road and provides access to the adjacent property will be modified. These modifications include a horizontal and vertical realignment to connect to the raised cross road. The profile grade will increase from 3.3% to 4.7%.

No additional R/W is required for these improvements.

4.12.16 Ramp Type Recommendations

The purpose of this section is to document the recommendation of ramp terminal, taper-type or parallel-type, at the interchanges within the study limits. Taper-type terminals are advantageous since they have a smaller footprint and generally result in reduced cost and environmental impacts. Parallel-type terminals generally provide improved traffic operations due to their longer merge and diverge lengths versus taper-type terminals.

Taper-type ramp terminals are common and are typically used in rural environments. The recommendations herein are based on operational analyses and geometric warrants for a parallel-type terminal in lieu of the standard taper-type ramp terminal. The taper-type ramp provides a direct entry or exit at a flat angle, whereas the parallel-type provides an added lane for changing speed.

The ADOT RDG indicates that new or reconstructed entrance and exit ramps on the urban and urban/fringe urban freeways of Metropolitan Phoenix and Tucson shall be designed as parallel-type ramps except in the vicinity of a directional interchange, where an analysis should be done to determine the preferred type. On a case basis, freeway exit and entrance ramps in other urban areas such as Yuma, Flagstaff, and Kingman should be evaluated for parallel-type versus taper-type design.

Grades
According to the RDG, ramp grades should be as flat as feasible and consistent with the design standards of the through highway. The desirable maximum upgrade is 4.0% and the desirable maximum downgrade is 5.0%. The impact of steep upgrades on vehicle speed must be considered. The horizontal and vertical alignments should provide ramp lengths sufficient for on-ramp traffic to accelerate to the mainline speed before entering the mainline traffic lanes and for off-ramp traffic to comfortably decelerate before reaching the queue at the cross road intersection.

Based on the AASHTO *A Policy on the Geometric Design of Highways and Streets*, 2004, passenger car acceleration rates are not affected by entrance ramp grades up to 5%; however, trucks are affected. Passenger cars will reach the desired speed before reaching the ramp gore, but trucks will attain a speed less than the desired speed at the ramp's terminus (10 mph less than the mainline design speed). Providing additional acceleration length could be a solution if the mainline has a downgrade or relatively flat grade. However, the terrain is rolling in the study area. Additional acceleration length would not be a solution for the entrance ramps on a steep upgrade because the trucks would not be able to accelerate to a speed greater than 35 mph until they are past the crest of the steep grade.

Mainline and Ramp Operational Level of Service
The analysis also used projected traffic volumes for the mainline and ramps to estimate and compare the design-year LOS of each ramp merge or diverge movement.

Many of the on- and off-ramps within the study area are expected to operate at a LOS worse than the target LOS. A secondary analysis was conducted assuming the existing taper-type ramps were reconstructed with a longer taper length or as parallel-type ramps. The results of this analysis are summarized in the I-40 *Preliminary Traffic Report*, March 2010, and are incorporated into Table 59 below.

Recommendations
The recommendations for the ramp terminal type for each existing and proposed ramp along I-40 within the study limits are listed in Table 59 that begins on the following page. The table entries include ramp grades, ramp merge and diverge LOS in the design year, the proposed ramp type, and comments supporting the recommendations.

4.13 Utilities

During final design, each utility company will receive and review the preliminary design for this project and develop plans for any relocations and/or adjustments.

The City of Flagstaff plans new utility lines across I-40 over the next 25 years as follows:

Reclaimed Water:

- Fourth Street bridge - 12" diameter (dia) loop from Sinagua to Sunnyside (24" casing)

Sewer:

- Flagstaff Ranch road sewer crossing - 12" dia
- Switzer Canyon - 21" dia to a 27"dia (upsize existing)
- Steves Blvd Wash - 15" dia to 21" dia (upsize existing)
- Fanning Drive Wash - 12" dia (upsize existing; future size to be determined)
- Rain Valley Wash - 10"

Water:

- West Flagstaff TI, Route 66 - 12" (24" casing) (long term future)
- Flagstaff Ranch Road - 18" dia (30" casing)
- Woody Mtn Road - 12" dia loop Zone A+ waterlines (24" casing)
- East Red Gap Ranch-Rain Valley crossing (long term future)

The planned crossings are reflected on the plan sheets in Appendix C.

Using as-built plans, plans supplied by the utility companies, and the conceptual plans developed for I-40 as references, it is anticipated that several utility relocations and adjustments may be necessary. For example, the following utility conflicts are anticipated:

- Realignment of the north frontage road at the new Camp Navajo TI will likely result in utility impacts
- At A-1 Mountain, rockfall mitigation measures will affect APS poles
- Overhead power lines cross I-40 near the new Lone Tree TI
- Overhead power lines will conflict with the new US 89 TI

Where the mainline and cross road profiles are being raised, vertical clearances need to be checked to ensure that overhead utilities are not affected. Where profiles are lowered, conflicts with underground utilities may need to be mitigated.

Table 59 – Ramp Type Recommendations

Ramp Location	In Direction of Traffic		2040 Design Mainline LOS	2040 Ramp Merge/Diverge LOS and Density TAPER	2040 Ramp Merge/Diverge LOS and Density PARALLEL	Relative Truck Volume	Proposed Ramp Type	Comments and Constraints
	Up Grade*	Down Grade*						
New Camp Navajo TI (MP 183.66) UP								
EB Exit	+2.0%		C	D-34.2	C-22.3	Medium	Taper	
EB Entrance		-2.6%	C	C-22.7		Medium	Parallel	Adds third lane
WB Exit	+4.0%		C	C-25.5		Medium	Parallel	Drops third lane
WB Entrance		-2.2%	C	D-32.6	C-27.0	Medium	Taper	
Bellemont TI (MP 185.15) UP								
EB Exit	+4.3%		C	C-25.6		High	Taper	
EB Entrance		-3.7%	C	D-28.4	C-23.6	High	Taper	Increase taper length
WB Exit	+1.7%		C	D-29.0	C-25.2	High	Taper	Increase taper length
WB Entrance		-4.6%	C	C-24.8		High	Taper	
A-1 Mountain TI (MP 190.54) UP								
EB Exit	+3.1%		C	C-27.2		Low	Taper	
EB Entrance		-4.0%	C	C-22.2		Low	Taper	
WB Exit	+4.1%		C	C-27.3		Low	Taper	
WB Entrance		-2.7%	C	C-22.0		Low	Taper	
West Flagstaff TI (MP 191.69) OP								
EB Exit		-4.0%	C	D-28.3	B-16.4	Medium	Taper	Increase taper length
EB Entrance (Loop)	+4.5%		C	B-19.0		Medium	Parallel	Loop ramp (26 mph)
WB Exit (Loop)	+0.3%		C	C-24.0		Medium	Parallel	Loop ramp (29 mph)
WB Entrance	2.3%		C	C-23.6		Medium	Taper	
Flagstaff Ranch TI (MP 192.56) OP								
EB Exit		-4.9	C	C-24.2		Low	Taper	
EB Entrance	+0.5%		C	B-19.5		Low	Taper	
WB Exit		-1.2	C	C-24.6		Low	Taper	
WB Entrance	+3.8%		C	B-19.2		Low	Taper	
New Woody Mtn TI (MP 193.47) UP								
EB Exit	+2.2%		C/D	C-24.5		Low	Taper	
EB Entrance		-2.8%	C/D	C-23.1		Low	Taper	
WB Exit	+4.5%		C/D	D-28.3		Low	Taper	
WB Entrance		-1.4%	C/D	B-19.5		Low	Taper	

Ramp Location	In Direction of Traffic		2040 Design Mainline LOS	2040 Ramp Merge/Diverge LOS and Density TAPER	2040 Ramp Merge/Diverge LOS and Density PARALLEL	Relative Truck Volume	Proposed Ramp Type	Comments and Constraints
	Up Grade*	Down Grade*						
I-40/I-17 System TI (MP 195.42)								
NB-EB ---DIVERGE	+3.3%		C/D	D-31.5	C-27.9	Medium	Parallel	Exist 2-lane exit
NB-WB (Loop) --- DIVERGE	+4.3%		C/D	C-23.7		Medium	Taper	
SB-EB (Loop) --- DIVERGE	+2.2%		C/D	B-19.2		Low	Parallel	Exist parallel exit
SB-WB--- DIVERGE	+4.1%		C/D	C-23.7		Low	Parallel	Exist auxiliary lane
EB-NB--- DIVERGE	+1.6%		C/D	D-29.1	C-25.5	Medium	Taper	
EB-SB--- DIVERGE	+2.1%		C/D	D-29.1	C-25.5	Medium	Taper	Increase taper length
WB-NB--- DIVERGE	+1.3%		C/D	B-16.3		Low	Parallel	Auxiliary lane connects from WB entrance ramp (New Lone Tree TI)
WB-SB--- DIVERGE	+1.7%		C/D	B-16.3		Medium	Parallel	Auxiliary lane connects from WB entrance ramp (New Lone Tree TI)
NB-EB ---MERGE	+1.2%		C/D	C-22.0		Medium	Parallel	Auxiliary lane connects to EB exit ramp (New Lone Tree TI)
NB-WB (Loop) --- MERGE		-0.9%	C/D	C-19.5		Medium	Parallel	Long parallel section to accom. SB-WB merge; bridge widening required
SB-EB (Loop) --- MERGE	+1.1%		C/D	C-25.9		Low	Parallel	Parallel ramp merges west of NB-EB ramp merge; bridge widening required
SB-WB--- MERGE		-1.2%	C/D	C-23.0		Low	Parallel	Bridge widening required
EB-NB--- MERGE	+3.3%		C/D	B-19.0		Low	Parallel	Exist parallel ramp from left side
EB-SB--- MERGE	+0.3%		C/D	A-9.5		Medium	Parallel	Exist parallel ramp merges to WB-SB ramp
WB-NB--- MERGE	+4.9%		C/D	C-27.2		Low	Parallel	Existing auxiliary lane
WB-SB--- MERGE		-2.9%	C/D	A-9.5		Medium	Parallel	Exist parallel ramp
New Lone Tree TI (MP 196.70) OP								
EB Exit		TBD	C/D	D-31.8		Low	Parallel	Auxiliary lane connects from I-40/I-17 NB-EB ramp
EB Entrance	TBD		C/D	C-23.0		Low	Parallel	Auxiliary lane connects to EB exit ramp (Butler TI)
WB Exit		TBD	C/D	D-29.9		Low	Parallel	Auxiliary lane connect from WB entrance ramp (Butler TI)
WB Entrance	TBD		C/D	C-24.4		Low	Parallel	Auxiliary lane connects to I-40/I-17 WB-NB/SB ramps
Butler TI (MP 198.28) OP								
EB Exit		-2.7%	C/D	D-33.8		High	Parallel	Auxiliary lane connects from EB entrance ramp (Lone Tree TI)
EB Entrance	+3.7%		C/D	D-29.2		High	Parallel	High percentage of trucks with upgrade
WB Exit		-1.2%	C/D	D-33.7		High	Taper	
WB Entrance	+4.0%		C/D	D-28.1		High	Parallel	Auxiliary lane connects to WB exit ramp (Lone Tree TI)
Country Club TI (MP 201.10) UP								
EB Exit	+6.0%		C/D	D-34.9		Medium	Taper	
EB Entrance		-2.6%	C/D	C-25.0		Medium	Taper	
WB Exit	+2.7%		C/D	D-29.6		Medium	Taper	
WB Entrance		-5.5%	C/D	D-31.1		Medium	Taper	
New US 89 TI (MP 202.31) UP								
EB Exit	+2.1%		C/D	D-30.2		High	Taper	
EB Entrance		-3.0%	C/D	B-19.0		High	Taper	
WB Exit	+3.9%		C/D	C-23.9		High	Taper	
WB Entrance		-3.9%	C/D	C-25.8		High	Taper	
Walnut Canyon TI (MP 204.87) UP								
EB Exit	+4.5%		C/D	C-23.9		Medium	Taper	
EB Entrance		-4.0%	C/D	B-18.8		Medium	Taper	
WB Exit	+3.9%		C/D	C-23.7		Medium	Taper	
WB Entrance (New Diagonal)		-2.4%	C/D	B-19.4		Medium	Taper	
Cosnino TI (MP 207.24) UP								
EB Exit		-1.2%	C	C-23.9		Low	Taper	
EB Entrance		-4.9%	C	B-17.1		Low	Taper	
WB Exit (New Diagonal)	+5.0%		C	C-22.1		Low	Taper	
WB Entrance		-1.9%	C	B-19.3		Low	Taper	

Ramp Location	In Direction of Traffic		2040 Design Mainline LOS	2040 Ramp Merge/Diverge LOS and Density TAPER	2040 Ramp Merge/Diverge LOS and Density PARALLEL	Relative Truck Volume	Proposed Ramp Type	Comments and Constraints
	Up Grade*	Down Grade*						
Winona TI (MP 211.16) UP								
EB Exit	+4.5%		C	D-31.3	B-19.4	Low	Taper	Increase taper length
EB Entrance		-5.4%	C	C-26.5		Low	Taper	
WB Exit	+4.8%		C	D-30.2	B-18.2	Low	Taper	Increase taper length
WB Entrance	+0.2%		C	C-27.7		Low	Taper	

* Ramp grades for the proposed future interchanges are based on current conceptual design and are subject to change during final design.

4.14 Structure Considerations

4.14.1 Existing Bridges

Most of the existing bridges within the corridor are in good condition with satisfactory sufficiency ratings. However, many also have functional issues typically related to vertical and lateral clearances and are listed as "functionally obsolete" in the *Arizona State Highway System Bridge Record*. Others have structural or load capacity issues and are listed as "structurally deficient."

The improvements to overpass structures within the project corridor include providing adequate deck width for the new mainline cross section, improving roadway geometry, providing required vertical and lateral clearances, and improving drainage where needed. In all cases, the existing overpass bridges lack deck width to accommodate the widened I-40 roadway cross section and, at most locations, vertical and lateral clearances do not conform to current standards. Mainline roadway widening could reduce existing vertical clearances due to cross road profile grades and existing bridge deck cross slopes. In some locations, adjusting the cross road profile can improve vertical clearance, but does not improve the lateral clearance.

The proposed typical eastbound and westbound cross section through a majority of this corridor is 60 feet wide; it will provide three 12-foot general purpose travel lanes and two 12-foot shoulders. The existing underpass bridges at the Bellemont TI UP, Woody Mountain Road UP, and Walnut Canyon TI UP do not provide adequate span arrangements to accommodate the new roadway cross section.

A summary of proposed improvements to the existing structures is shown in Table 60.

Table 60 – Recommended Improvements to Existing Bridges

STR NO.	MP	LOCATION	COMMENTS	ACTION			
				NONE	WIDEN	REPLACE	OTHER
783	185.15	Bellemont TI UP EB	Lateral clearance			X	
1083	185.15	Bellemont TI UP WB	Lateral clearance			X	
896	190.54	A-1 Mountain TI UP	Replace bridge barrier				X
332	190.86	Riordan at BNSF RR OP EB	Mainline re-alignment			X	
897	190.86	Riordan at BNSF RR OP WB	Mainline re-alignment			X	
1128	191.69	W. Flagstaff TI OP EB	Load capacity & clearances			X	
1129	191.69	W. Flagstaff TI OP WB	Load capacity & clearances			X	
2027	192.56	Flagstaff Ranch TI OP EB	Inadequate deck width		X		
2020	192.56	Flagstaff Ranch TI OP WB	Inadequate deck width		X		
1132	193.47	Woody Mountain Road UP EB	Load capacity & clearance			X	
1133	193.47	Woody Mountain Road UP WB	Horizontal clearance			X	
1262	195.22	Hwy 89A OP WB	Non-conforming superelevation			X	
1261	195.22	SR 89A OP EB	Non-conforming superelevation			X	
1263	340.02 *	I-40 TI OP EB	Non-conforming superelevation			X	
1264	340.02 *	I-40 TI OP WB	Non-conforming superelevation			X	
1180	196.26	Lone Tree Road OP EB	Load capacity & clearances			X	
1181	196.26	Lone Tree Road OP WB	Load capacity & clearances			X	
1482	197.43	Rio de Flag Br EB	Inadequate deck width		X		
1483	197.43	Rio de Flag Br WB	Inadequate deck width		X		
2076	198.28	Butler Avenue TI OP EB	Inadequate deck width		X	X **	
2077	198.28	Butler Avenue TI OP WB	Inadequate deck width		X	X **	
1182	199.3	Fourth Street UP EB	Corridor study & clearances			X	
1183	199.3	Fourth Street UP WB	Corridor study & clearances			X	
1926	201.1	Country Club TI UP	Re-profile I-40		X		
1270	204.87	Walnut Canyon TI UP EB	Load capacity & clearance			X	
1271	204.87	Walnut Canyon TI UP WB	Load capacity & clearance			X	
1361	207.24	Cosnino TI UP	Re-align I-40 & TI	X			
2431	210.24	Walnut Canyon Bridge WB	Canyon bridge	X			
2588	210.24	Walnut Canyon Bridge EB	Canyon bridge	X			
1084	211.16	Winona TI UP	Load capacity & clearances			X	

* Milepost based on I-17

** Widen or replace, depending on which alternative is recommended.

To minimize the effects on mainline and cross road profiles, the structure depths of the new bridges require careful consideration. In most cases when comparing structure options, precast/prestressed concrete bridge elements are recommended over steel elements due to their availability, familiar construction techniques, reduced maintenance, and cost savings. However, steel girders may provide a suitable alternative in situations where structure depth is critical and span lengths must exceed those of precast/prestressed concrete girders. When determining span lengths, 2:1 abutment foreslopes were assumed and a 30-foot clear zone was used.

Accelerated Bridge Construction (ABC) techniques are currently used in many states to minimize impacts to existing traffic during bridge replacements and new bridge construction. In an effort to reduce construction time, one possible technique would be to build a bridge's superstructure and substructure concurrently by constructing the superstructure at a different location and then moving it into place using Self Propelled Modular Transports (SPMTs). It is recommended that ABC techniques be considered and evaluated during the final design of structures to minimize construction time, traffic delays and road closures.

Overpass Bridges

Riordan BNSF Railroad OP Eastbound and Westbound

The Riordan BNSF Railroad OP bridges consist of individual 507-foot long eastbound and 396-foot long westbound structures crossing two tracks and a BNSF maintenance road, a small wash, and Observatory Road. Due to I-40 mainline re-alignment and profile adjustments, the existing bridges have to be replaced. The Riordan BNSF Railroad OP bridges are located approximately 1800 feet to the east of the A-1 Mountain TI OP and about 0.75 mile west of the West Flagstaff TI OP. Profile changes at the Riordan BNSF Railroad OP could affect the A-1 Mountain TI OP vertical clearance.

Currently, BNSF operates two tracks in this area but has expressed interest in constructing an additional track. The BNSF design guidelines call for a minimum horizontal clearance of 25 feet between bridge substructure and the centerline of the closest existing or future track. ADOT design guidelines require a minimum vertical clearance of 23'-6" over the top of rail at railroad crossings. Possible structure types over the BNSF railroad must account for this future track.

Assumptions made while evaluating potential structure types over the railroad are as follows:

- It was assumed that construction of any future track would take place to the south based on the current track layout and the surrounding topography.
- The new track would be spaced at 15 feet from the centerline of the existing exterior track.
- The existing tracks are located at the top of a slope approximately nine feet above the existing maintenance road; therefore, any future track would be at or below the elevation of the existing tracks.
- The existing maintenance road would be shifted from its current location to account for a future track location.

To accommodate the possible future track in this area, potential structures could utilize welded plate girders to achieve desirable clear openings. Typically PC/PS concrete elements are considered due to their availability, reduced maintenance and cost; however, the longer spans afforded by steel welded plate girders make them excellent choices here. A future track can be accommodated using welded steel plate girders with a main span length of 145 feet. Because these are bridge replacements, the use of steel girders will facilitate staged construction to reduce traffic disruptions and closures.

Another potential structure type combines PC/PS concrete elements with CIP post-tensioned (PT) concrete elements. The bridge end spans can be designed as a CIP PT box girder bridge with cantilevers extending past each pier about 25 feet. The center span can be designed using PC/PS AASHTO Type V or Type VI girders. Standard AASHTO Type V or Type VI girders can be designed for a clear bridge opening on the order of 120 feet to 140 feet. An advantage of this method is it "extends" the span length of precast girders by taking advantage of CIP bridge construction over the zone allotted for future tracks.

PC/PS concrete AASHTO Type Super VI girders can be designed for spans up to 145 feet which could provide another option for spanning the railroad. However, due to the size and weight of these girders, this option must be investigated further to address erection challenges in the vicinity of the railroad.

West Flagstaff TI OP

The existing West Flagstaff TI OP bridges consist of independent eastbound and westbound, three-span reinforced concrete T-girder bridges, each approximately 123 feet long. The 2008 ADOT bridge inspection report lists both bridges as having non-conforming underclearances and load capacity. The vertical clearance of the bridges are 15'-0" and 15'-3", respectively. The Inventory Rating is HS-15 for eastbound and HS-14.4 for westbound. It is recommended these bridges be replaced.

The eastbound mainline lanes will be widened to both the inside and outside, whereas the westbound mainline widening occurs only toward the inside. Constructability, minimizing traffic disruptions, and minimizing structure depth are key concerns for these bridges. Staged construction using precast elements in addition to ABC techniques could greatly reduce traffic disruptions and closures during construction.

One possible structure type for use at this location is a three-span precast/prestressed AASHTO Type IV girder bridge. A three-span option allows for a shallower structure depth and precast AASHTO girders allow for quicker, standardized construction. The profile of I-40 will need to be raised approximately 3-5 feet to provide for the new structure depth and necessary vertical clearance.

Other possible structure types and configurations considered include:

- Precast/prestressed, three-span box beam bridge
- Precast/prestressed, three-span AASHTO Type III girder bridge
- Precast/prestressed, single-span AASHTO girder bridges with tall abutments

Flagstaff Ranch TI OP

As part of the proposed improvements to the Flagstaff Ranch TI OP, it is recommended that the existing 155-foot long, single span, CIP PT box girder bridge be widened in like kind. Due to the span length, widening the existing bridge in like kind will provide better continuity between the original and widened structure. Problems can occur when widening bridges using dissimilar superstructure types as a result of the differing stiffness associated with unlike elements.

At this location, mainline widening will take place to the inside; as such, widening the existing structure will not reduce current vertical clearance over Flagstaff Ranch Road. However, according to the 2008 ADOT bridge inspection reports for this structure, the minimum vertical clearance of westbound I-40 over Flagstaff Ranch Road is 15'-10". A design exception will be requested.

Planned expansion of the FUTS in this area will utilize the Flagstaff Ranch TI OP to cross under I-40. New substructure elements will accommodate the trail expansion. However, replacing the bridge or shortening the bridge abutment foreslopes using retaining walls is not included in the overall I-40 design concept.

Access must be maintained during bridge construction. Record drawings for the cross road show buried gas and power utilities.

Bridge widening over Flagstaff Ranch Road must account for the reduced vertical clearance resulting from the falsework associated with CIP box girder bridge construction. Options to consider include:

- Reduce the number travel lanes during construction to allow for shallower falsework.
- Overexcavate the cross road during construction to provide vertical clearance.
- Construct the new superstructure higher than required and then lower the completed structure into place.

SR 89A OP

Proposed improvements to I-40 at the SR 89A OP include adjustments to the mainline geometry, widening both the eastbound and westbound lanes approximately 20 feet toward the median, and a tapered outside widening near the westbound bridge to accommodate Ramp S-W of the I-40/I-17 system TI. The required mainline superelevation for both eastbound and westbound I-40 in this area is slightly over 3%. The existing 347-foot long, 6-span reinforced concrete box girder bridges are 44 years old and as-built drawings show the deck cross slope is 1.5%. The cost associated with widening and changing the cross slope of these older bridges would be prohibitive; as such, it is recommended the existing bridges be replaced to meet current design standards.

Because the bridges at the SR 89A OP are within the I-40/I-17 system TI, constructability, reducing impacts to mainline profile, and minimizing traffic disruptions are primary concerns. Staged construction using precast elements as well as ABC techniques could be used to reduce traffic disruptions and closures during construction. These bridges also provide a crossing location for the FUTS under I-40 and trail access must be considered during construction.

According to the 2008 bridge inspection reports, the current vertical clearance over SR 89A is over 24 feet at the eastbound bridge and over 22 feet at the westbound bridge. Longer spans and deeper superstructures could be utilized while still maintaining necessary vertical clearance requirements and minimizing I-40 mainline profile adjustments. Standard PC/PS AASHTO Type IV or Type V girders can be designed for a clear bridge opening on the order of 100 feet to 120 feet. Various structure types were considered as replacements, most of which use precast concrete elements to reduce construction time. One possible option for this structure is a three-span precast/prestressed AASHTO Type V girder bridge. Precast/prestressed concrete elements allow for quick, standardized and phased construction.

Other possible structure types and configurations considered include:

- Precast/prestressed, six-span box beam bridges
- Precast/prestressed, six-span AASHTO Type III girder bridges
- Precast/prestressed, two-span CIP PT box girder bridges

I-40 TI OP

The bridges at the I-40 TI OP are also within the I-40/I-17 system TI; these bridges are approximately 900 feet east of the SR 89A OP bridges. Similar to the SR 89A location, mainline improvements include adjustments to the mainline geometry and superelevation for both eastbound and westbound I-40. Median and outside mainline widening will increase the I-40 roadway cross section to about 75 feet at this location due to the proximity of I-17/ I-40 system TI ramps N-W and S-E.

The existing 213-foot long, 4-span reinforced concrete box girder bridges are 44 years old. Record drawings show the deck cross slope is 1.5%. According to the 2008 bridge inspection reports, both eastbound and westbound bridges are reported to have non-conforming underclearances and low deck geometry ratings and, as such, both bridges are listed as functionally obsolete. Vertical clearance at both eastbound and westbound bridges is reported at 16'-3" and widening the structures would further reduce the vertical clearance. It is recommended that both bridges be replaced.

Due to the proximity of the SR 89A OP to the west and the I-40 Ramp W-S over Lake Mary Road flyover, reducing impacts to the I-40 profile are key concerns. Minimizing traffic disruptions and constructability are also important issues at this location. Possible structure types must provide adequate vertical clearance over I-17 below while limiting profile changes to I-40, which in turn will reduce the vertical clearance to the ramp above.

The 2008 bridge inspection report for the Ramp W-S over Lake Mary Road flyover lists a vertical clearance for the ramp bridge over the I-40 eastbound lanes as 19'-1½" and over the westbound lanes as 18'-9". In order to maintain a minimum vertical clearance of 16'-6" over the westbound lanes, the westbound profile can be raised a maximum of 2'-3" and, assuming the same vertical clearance at the eastbound lanes, the profile can be raised by a maximum of 2'-7½".

Various structure types were considered as replacements, most of which use precast concrete elements to reduce construction time. One possible option for this structure is a two-span precast/prestressed AASHTO Type IV girder bridge. The increase to the I-40 profile associated with this type of structure is approximately 1'-10", which will still provide the necessary vertical clearance at the Ramp W-S flyover bridge.

Other possible structure types and configurations considered include:

- Precast/prestressed, four-span box beam bridges
- Precast/prestressed, four-span AASHTO Type III girder bridges
- Precast/prestressed, two-span CIP PT box girder bridges

Lone Tree Road OP

The Lone Tree Road OP bridges consist of 107-foot long, 3-span continuous concrete slab bridges, skewed at approximately 26°. The bridges were constructed in 1966. The 2008 ADOT bridge inspection reports show evidence of truck collisions with the existing bridges. Both bridges have been classified as functionally obsolete due to underclearance dimensions as well as reduced load carrying capacity. Re-profiling the cross road to improve vertical clearance has been ruled out due the high water table in this area. With the combination of mainline improvements at the new Lone Tree TI and the high water table possibly restricting profile adjustments at Lone Tree Road, it is recommended that the existing bridges be replaced.

Constructability, minimizing structure depth, and minimizing traffic disruptions are primary concerns at this location. Configuration and construction of the new Lone Tree TI OP approximately 1800 feet to the east of the existing bridges will influence the number and type of structures at Lone Tree Road. The mainline cross section at this location will nearly double in width and a new bridge will be required due to the proximity of the new braided ramps. Structure depth can affect the mainline and ramp profiles of the new Lone Tree TI.

One possible structure type for use at the Lone Tree OP is a three-span precast/prestressed AASHTO Type III girder bridge. Standard PC/PS AASHTO Type III girders can be designed for a clear bridge opening on the order of 80 feet. Providing a center span of up to 80 feet will provide required clear zone distances and accommodate possible future widening of Lone Tree Road.

A three-span option allows for minimal disruptions to Lone Tree Road traffic and a shallower structure depth and precast AASHTO girders allow for faster, standardized construction that can be incorporated into staged construction phasing when replacing structures. Variable deck widths can be accommodated through use of flared girder spacing or the use of surplus bridge deck. Any modifications to the Lone Tree Road OP structures must account for future mainline adjustments at the New Lone Tree TI to the east. The Lone Tree Road OP is a crossing location for the FUTS and trail access must be considered during construction.

Other possible structure types and configurations considered include:

- Precast/prestressed, three-span box beam bridges
- Precast/prestressed, two-span AASHTO Type IV girder bridges
- Precast/prestressed, single-span AASHTO Type VI girder bridges with tall abutments

Butler Avenue TI OP

The existing bridges at the Butler Avenue TI OP were constructed in 1988; they are approximately 250 feet long, 3-span steel girder bridges and skewed at approximately 45°. They are in good condition, with sufficiency ratings of 96.01. Vertical clearances at the Butler Avenue bridges are slightly lower than current requirements, with the eastbound bridge listed at 16'-5" and the westbound bridge listed at 16'-3". Multiple options are being considered as part of the proposed improvements to the Butler Avenue TI OP.

Possible options include reconfiguring the interchange by replacing the signalized intersections with roundabouts and reconfiguring the ramp geometry, or keeping signalized intersections but reconfiguring the interchange geometry using either a diamond or a double crossover configuration.

By replacing the signalized intersections with roundabouts and reconfiguring the ramp geometry, the Butler Avenue cross section can be accommodated within the existing bridge span arrangement. The existing bridges can be salvaged and widened in like kind to accommodate the increased width of the I-40 mainline. However, widening the bridge deck will further reduce the vertical clearance at the eastbound I-40 bridge by approximately two inches. As part of the proposed improvements to Butler Avenue, the profile will be adjusted to provide the required vertical clearances at the bridges.

The existing center span of the bridges does not provide adequate space for the proposed sidewalks. The end spans of each three-span bridge can be used to accommodate the sidewalks. At both bridges, the abutment foreslopes can be shortened and retaining walls constructed to provide the needed area for the sidewalks.

If the preferred alternative is to reconfigure the interchange geometry with a signalized diamond or a double crossover design, the existing bridges must be replaced to accommodate the changes to the Butler Avenue cross section. As with other locations, various structure types were considered, with concerns including constructability, traffic disruptions, and structure depth. The lane configuration of the diamond option does not provide a wide enough median for a center pier necessary for a two-span bridge arrangement. The pedestrian sidewalk is located within the center median in the double crossover configuration, which also precludes the use of a center pier.

The required roadway cross section for both the diamond and double crossover alternatives is approximately 110 feet; however, because of the skew of the mainline over Butler Avenue, the estimated span length for replacement bridges would be in the range of 150 feet to 160 feet. A potential structure type to achieve the required clear opening could utilize welded steel plate girders. Because these are bridge replacements, the use of steel girders would facilitate staged construction to reduce traffic disruptions and closures. Longer span lengths require deeper superstructures; as such, mainline profile adjustments would be needed to accommodate the deeper structure and to provide the necessary vertical clearance over Butler Avenue.

Other possible structure types and configurations considered include:

- Cast-in-place, post-tensioned concrete box girder bridges
- Precast/prestressed, two-span AASHTO Type IV girder bridges (This option would require increasing the median width to provide room for a center pier.)
- Three-span bridge using a combination of CIP PT box girder end spans with a PC/PS AASHTO Type V center “drop in” center span which has the advantage of extending the effective span length of precast concrete girders.

Underpass Bridges

Bellemont TI UP

The Bellemont TI UP will be reconstructed approximately 800 feet to the east. The need to relocate the cross road is driven by growth and development in the area and the need for improved TI operations. Shifting the interchange location will also reduce impacts to the existing cross road traffic and aid in constructability.

Various structure types were considered as replacements, all of which use precast concrete elements. One option for the new Bellemont TI UP is a precast/prestressed, five-span AASHTO Type IV girder bridge. Standard PC/PS AASHTO Type IV or Type V girders can be designed for a clear bridge opening on the order of 100 feet to 120 feet. Providing a center span of 100 feet will provide required clear zone distances and accommodate the widened I-40 roadway section.

Other possible structure types and configurations considered include:

- Precast/prestressed, independent eastbound and westbound, three-span AASHTO Type IV girder bridges
- A single precast/prestressed, two-span Type VI girder bridge with tall abutments
- Precast/prestressed, independent eastbound and westbound, single-span Type VI girder bridges with tall abutments

A-1 Mountain TI UP

The bridge at A-1 Mountain TI UP is a 302-foot long, 4-span steel girder bridge, with ends spans of 47'-3" and interior spans of 99'-9". Vertical clearances at A-1 Mountain meet ADOT requirements and existing span lengths provide adequate lateral clearances for the new I-40 roadway cross section. The existing bridge barrier on the A-1 Mountain bridge does not conform to current AASHTO geometric or structural requirements. As such, the bridge barrier should be replaced to meet current AASHTO requirements.

New Woody Mountain TI UP

As part of the proposed I-40 improvements at Woody Mountain Road, the existing grade separation is proposed to be reconfigured with roundabouts at the ramp/cross road intersections. The bridges at Woody Mountain Road UP are approximately 178 feet long, 3-span reinforced concrete T-girder bridges. The center spans of the bridges are not long enough to accommodate the widened I-40 roadway section. Additionally, the inventory ratings of the bridges are HS-19.4 and HS-20. It is recommended that existing structures be replaced.

As with other locations, constructability and minimizing traffic disruptions and structure depth are primary concerns. Various structure types were considered as replacements, all of which use precast concrete elements. Additionally, phased construction was considered in order to maintain traffic on Woody Mountain Road during construction. Flagstaff Ranch TI OP is less than a mile to the west and could temporarily provide a detour for cross road traffic during bridge construction. Because the mainline is to be re-aligned, the profile will be adjusted to reduce impacts to the profile of the existing cross road and surrounding development.

Standard PC/PS AASHTO Type IV or Type V girders can be designed for a clear bridge opening of approximately 100 feet to 120 feet. One option for the Woody Mountain TI UP is independent eastbound and westbound precast/prestressed, three-span AASHTO Type V girder bridges. Because Woody Mountain Road is skewed at approximately 28°, Type V girders are required for the center span of approximately 110 feet. If required, variable deck widths can be accommodated through use of flared girder spacing or the use of surplus bridge deck.

Other possible structure types and configurations considered include:

- A single precast/prestressed, three-span Type VI girder bridge
- Precast/prestressed, independent eastbound and westbound, single-span Type VI girder bridges with tall abutments

Walnut Canyon TI UP

At the Walnut Canyon TI UP, each bridge is a 144’ long, 3-span steel girder bridge. Due to non-conforming lateral and vertical clearances, the bridges at Walnut Canyon have been listed as functionally obsolete. Vertical clearances for the bridges are 16'-0" and 16'-2½" for the eastbound and westbound bridges, respectively. The center spans of the bridges are not long enough to accommodate the increased I-40 roadway section. Additionally, the inventory ratings of both bridges are below HS-20. It is recommended that these structures be replaced.

The existing structure depth is approximately 3'-5"; the girders are W33x130 rolled shapes with a 7½” deck. To increase the length of the center span for the new bridge, a deeper structure depth will be required. Various structure types were considered as replacements, all of which use precast concrete elements. Standard AASHTO Type V girders can be designed for a clear bridge opening on the order of 110 feet to 120 feet. The realigned Walnut Canyon Road is skewed at approximately 18° to I-40. Type V girders are required for the span over I-40.

One potential structure type is a single, three-span AASHTO Type V girder bridge. This bridge configuration will result in a structure depth of about 6'-0". This increased structure depth will require cross road and ramp profile adjustments of approximately three feet. During a previous bridge rehabilitation project at the Walnut Canyon TI, traffic was detoured to the Country Club TI and the Cosnino TI during construction.

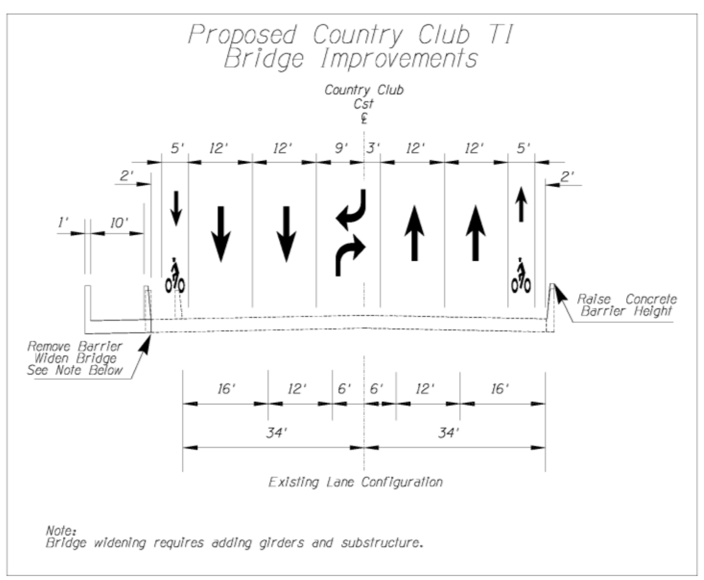
Other possible structure types and configurations considered include:

- Precast/prestressed, two-span Type VI girder bridge, with tall abutments
- Precast/prestressed, independent eastbound and westbound single-span Type VI girder bridges with tall abutments

Country Club TI UP

The Country Club TI UP bridge is a 367-foot long, 3-span precast prestressed concrete girder bridge. The end spans are 135 feet long and the center span is 92 feet. According to the 2008 ADOT bridge inspection reports for the Country Club TI UP, the minimum vertical clearance over westbound I-40 does not conform to current ADOT requirements. However, the span lengths of the existing bridge provide adequate lateral clearance to accommodate the new I-40 roadway cross section.

Proposed improvements at the Country Club TI UP include adding five-foot bicycle lanes in both directions and increasing the width of the FUTS trail on the east side of the bridge to ten feet. The current out-to-out bridge width is 78'-0". The addition of bike lanes and increased width of the FUTS trail would require widening the existing bridge to an out-to-out width of 88'-6". One possibility is to widen the existing bridge in like kind on the east side approximately 10'-6" to provide the necessary additional width.



This widening would require at least one additional girder line as well as additional substructure elements. Barrier on the west side of the bridge will require modification to meet height requirements for barrier adjacent to a bike lane. Combination pedestrian-traffic bridge railing and pedestrian fence will be required on the east side as well as new barrier between the travel lanes and the FUTS trail. Widening the existing bridge will further reduce the vertical clearance over westbound I-40. As a result, the westbound mainline profile will be lowered to provide the required vertical clearance at the structure.

Another option considered was constructing a new independent pedestrian bridge on the east side of the existing structure solely to accommodate the FUTS trail. This independent structure could be constructed to provide adequate vertical clearance over the mainline. However, this option does not eliminate necessary modifications to the existing bridge or required mainline profile adjustments to provide vertical clearances.

Fourth Street UP

Mainline improvements at Fourth Street include adding one general purpose lane in each direction and increasing shoulder widths to provide a 60 foot out-to-out roadway cross section. This area has also been identified by ADOT Materials Group as being a rock fall hazard area due to the steep cut slopes on each side of the roadway. The Fourth Street UP bridges consist of individual northbound and southbound structures constructed in 1968. The bridges are approximately 115-foot long simple-span welded plate girder bridges with a clear roadway width of 40 feet. According to the 2008 bridge inspection reports, vertical clearances at the bridges are 19'-11½" and 16'-5½".

The existing Fourth Street UP bridges have been recommended for replacement as part of another project initiated by the City of Flagstaff. The *Fourth Street – South Corridor Study* by the City of Flagstaff recommended replacing the existing steel bridges with concrete structures using PC/PS AASHTO Type Super VI girders. The new bridges will be 147'-6" simple spans with an out-to-out width of 94'-4". The increased width and increased structure depth of the new bridges will require adjusting the Fourth Street profile to provide the necessary vertical clearance over I-40.

Cosnino TI UP

The bridge at Cosnino TI UP is a 311' long, 5-span steel girder bridge. According to the 2008 bridge inspection report, the bridge is in good condition but has been classified as functionally obsolete due to non-conforming vertical clearance. The report states the bottom flanges of the girders over eastbound I-40 show scrapes possibly due to near collisions with trucks.

The existing interchange includes diamond ramps in southern quadrants and diagonal and loop ramps in the northwest quadrant. The recommended alternative re-configures the westbound exit and entrance ramps into a typical diamond configuration, eliminating the westbound loop exit. These modifications allow adjustments to the westbound horizontal alignment and mainline vertical profile in order to provide the required vertical clearance. Record drawings of the Cosnino TI bridge show 76'-0" clear openings at spans 2 and 4 and approximately 68'-0" between foundations. This provides adequate clear space for both vertical and horizontal adjustments of the typical 60 foot mainline roadway section between piers.

Winona TI UP

The Winona TI UP bridge consists of a five-span steel girder bridge with a sufficiency rating of 91.65. According to the 2008 bridge inspection report, the bridge has an Inventory Load Rating of HS-16.7 and has been classified as functionally obsolete due to non-conforming underclearances. Superstructure modifications may be possible to increase the load-carrying capacity of the bridge and re-profiling the mainline could improve vertical clearance issues. However, the existing structure is 43 years old and existing span lengths over I-40 are such that future widening of the mainline in this area would require replacing the bridge. Therefore, it is recommended that the existing bridge be replaced.

Key elements for consideration will be minimizing structure depth to reduce impacts on the ramps and adjacent intersections and maintaining traffic on Townsend-Winona Road during construction. One option would be to construct the new bridge a short distance to the east of the existing bridge. This method allows cross road traffic to be maintained during construction. Mainline traffic could be detoured onto the ramps during construction rather than closing the mainline.

Various structure types were considered as replacements, all of which use precast concrete elements. The overall length of the existing bridge is approximately 277 feet, with a maximum span length of 63'-6". The girders are W33x118 rolled shapes with a 7½" deck, for a structure depth of 3'-4 ½".

One potential structure type is a single, two-span AASHTO Type V girder bridge with tall abutments. Standard AASHTO Type V girders can be designed for a clear bridge opening on the order of 110 feet to 120 feet. The potential structure depth using AASHTO Type V girders is 6'-0". This is about a 2'-6" increase in structure depth over the existing bridge and with the required profile adjustments to provide the minimum vertical clearance, the existing cross road profile must be raised approximately 3'-2".

Other possible structure types and configurations considered include:

- Precast/prestressed, five-span AASHTO Type IV bridge
- Precast/prestressed, single-span AASHTO Type IV girder bridges with tall abutments
- Mainline re-profiling could reduce ramp and cross road adjustments

Canyon Bridges

Rio de Flag Bridges

The Rio de Flag bridges are approximately 320 feet long, 3-span precast prestressed concrete girder bridges constructed in 2005. The proposed eastbound and westbound mainline cross-section throughout the corridor is 60 feet; however, in the vicinity of the Rio de Flag bridges the proposed mainline cross-section will be increased to 70 feet due to the addition of an auxiliary lane. The mainline widening at the Rio de Flag bridges is to the outside at the westbound bridge but remains as inside widening at the eastbound bridge. It is recommended that both the eastbound and westbound bridges be widened in like kind to accommodate the increased roadway cross-section.

Walnut Canyon Bridges

The Walnut Canyon bridges are three-span precast prestressed concrete girder bridges; the westbound bridge constructed in 1997 and the eastbound bridge in 2001. The bridges are beyond the limits of the roadway widening portion of this project; therefore, no improvements to these bridges are recommended as part of this project.

New Interchange Structures

New Camp Navajo TI UP

Due to increased growth in the area and the need to provide improved access to Camp Navajo, the proposed Camp Navajo TI UP will be located at approximately MP 183.6. The new diamond interchange will consist of independent eastbound and westbound bridges over I-40. Various structure types were considered for these bridges, all of which employ precast concrete elements. One option is a three-span precast/prestressed concrete AASHTO Type IV girder bridge. Type IV girders can accommodate spans up to 100 feet and will provide adequate lateral clearance for future expansion of the mainline.

Other possible structure types and configurations considered include:

- Precast/prestressed, independent eastbound and westbound three-span AASHTO Type III girder bridges
- Precast/prestressed, independent eastbound and westbound single-span AASHTO Type VI girder bridges
- Precast/prestressed, four-span AASHTO Type V girder bridge

New Lone Tree TI UP/OP

The proposed New Lone Tree TI is located approximately 1800 feet east of the existing Lone Tree Road OP. The Braided Over and Braided Under alternatives are being considered. The Braided Over I-40 Alternative would require a new bridge to carry New Lone Tree Road over mainline I-40. Conversely, the Braided Under I-40 Alternative would require new bridges to carry mainline I-40 over New Lone Tree Road. Both alternatives require an additional bridge for the westbound braided ramp over or under the new Lone Tree westbound entrance ramp, as well as retaining walls. Both alternatives also require reconstruction of the existing Lone Tree Road OP as a result of adjustments to the mainline profile and alignment at the interchange.

The Braided Over I-40 Alternative structures must carry New Lone Tree Road over the I-40 mainline as well as the new westbound exit ramp serving I-17. Required span lengths for the span over westbound I-40 and the new westbound exit ramp are approximately 145 feet to 150 feet long. Potential structure types could utilize PC/PS AASHTO Type Super VI girders, cast-in-place, post-tensioned concrete box girders, or welded steel plate girders.

One option is a two-span precast/prestressed concrete AASHTO Type Super VI girder bridge with tall abutments. Type Super VI girders can accommodate spans up to 145 feet and would provide adequate span length for westbound I-40 and the new exit ramp. Barrier would be required between the new abutment and the right shoulder of the new westbound exit ramp. AASHTO girders allow for faster, standardized construction and fewer traffic disruptions.

Other structure types and configurations considered include:

- Cast-in-place post-tensioned concrete box girder bridge construction is typically avoided over mainline freeways due to the need for falsework during construction. Because of the difficulty associated with cast-in-place construction over the mainline I-40, this option is not recommended.
- Welded steel plate girder construction typically is not cost effective when compared to PC/PS concrete alternatives due to availability and increased maintenance.

The new structures for the Braided Under I-40 Alternative would consist of independent eastbound and westbound I-40 bridges over New Lone Tree Road. New Lone Tree Road would be depressed and portions of the mainline would be re-aligned and elevated at this location. Various structure types were considered for these bridges, all of which employ precast concrete elements. AASHTO girders allow for faster, standardized construction that can be incorporated into staged construction phasing when necessary. One option for these structures is a two-span precast/prestressed concrete AASHTO Type IV girder bridge. Type IV girders can accommodate spans up to 100 feet, providing adequate span lengths for the proposed roadway cross-section, FUTS trail, and abutment foreslopes.

Other structure types and configurations considered include:

- Precast/prestressed, three-span AASHTO Type IV girder bridge
- Precast/prestressed, single-span AASHTO Type VI girder bridge, with tall abutments

Where the westbound braided ramp crosses the New Lone Tree westbound entrance ramp, the two ramps cross at a high skew resulting in a structure approximately 410 feet long. One possible structure type would be a two-span cast-in-place concrete post-tensioned box girder bridge. Due to the high skew and long spans encountered on either alternative, the bridge should utilize full height abutments to keep the span lengths as short as possible and can be oriented normal to the ramp centerline. A single span cast-in-place concrete post-tensioned straddle bent would be required to span the ramp beneath.

Both alternatives will require the construction of new retaining walls. All walls are assumed to be standard ADOT cast-in-place concrete retaining walls; however, retaining walls could be designed as mechanically stabilized earth (MSE) walls if approved by ADOT.

The Braided Over I-40 Alternative would require retaining walls along westbound I-40 for the entrance and exit ramps, at the new bridge over the westbound exit ramp for traffic destined for southbound I-17 or Milton Road, and along the new Lone Tree I-17/Milton ramp. Wall heights would be dependent on the final roadway profiles at the interchange and the new ramp bridge, but would vary between a maximum of 30 feet at the bridges to about 4 feet near the ends of the ramps. Most wall lengths for this alternative are on the order of 650 feet; however, one wall along the new Lone Tree I-17/Milton ramp is estimated at 1100 feet.

Because the Braided Under I-40 Alternative assumes that the new Lone Tree Road will be depressed, the required amount of retaining walls can be reduced through the use of sloping fills at the ramps. Retaining walls would be required at the new bridge crossing the entrance ramp and along the new westbound exit ramp. Wall heights again would depend on the final roadway profiles at the interchange and the new ramp bridge, but would vary between a maximum of 30 feet at the bridge to about 4 feet near the ends of the ramps. Most wall lengths for this alternative are on the order of 500 to 700 feet long. The wall along the new Lone Tree I-17/Milton ramp could be shortened or possibly eliminated due to the wall required along the new westbound exit ramp.

New US 89 TI UP

The proposed new US 89 TI UP will be located approximately 1.25 mile east of the existing Country Club TI. The new interchange structures must cross eastbound and westbound I-40, two existing BNSF tracks, a railroad maintenance road, and US 180/East Santa Fe Avenue. The westbound exit and entrance ramps are situated between the railroad R/W on the north and westbound I-40 on the south. Due to the proximity of the BNSF bridge and the mainline, the westbound ramps will be approximately 1200 feet long and approximately 30 feet high where they intersect the cross road. The interchange configuration creates an intersection of the four bridges.

Potential structure types over the BNSF railroad must account for the addition of a future track. BNSF currently operates two tracks through this area but has identified plans for an additional track. The BNSF design guidelines call for a minimum horizontal clearance of 25 feet between bridge substructure and the centerline of the closest existing or future track. ADOT design guidelines require a minimum vertical clearance of 23'-6" over the top of rail at railroad crossings.

Assumptions made while evaluating potential structure types over the BNSF are as follows:

- It was assumed that any future expansion of the railroad will take place to the north of the existing tracks due to the location of a railroad siding about 2500 feet to the west of the new US 89 TI.
- The new track would be spaced at 15 feet from the centerline of the existing exterior track.
- The existing tracks are located at the base of a shallow cut. It was assumed that the existing cut would be enlarged and new tracks would be constructed at the same elevation as the existing tracks.
- The existing maintenance/access road will be shifted from its current location about 60 feet to the north under the first bridge span.

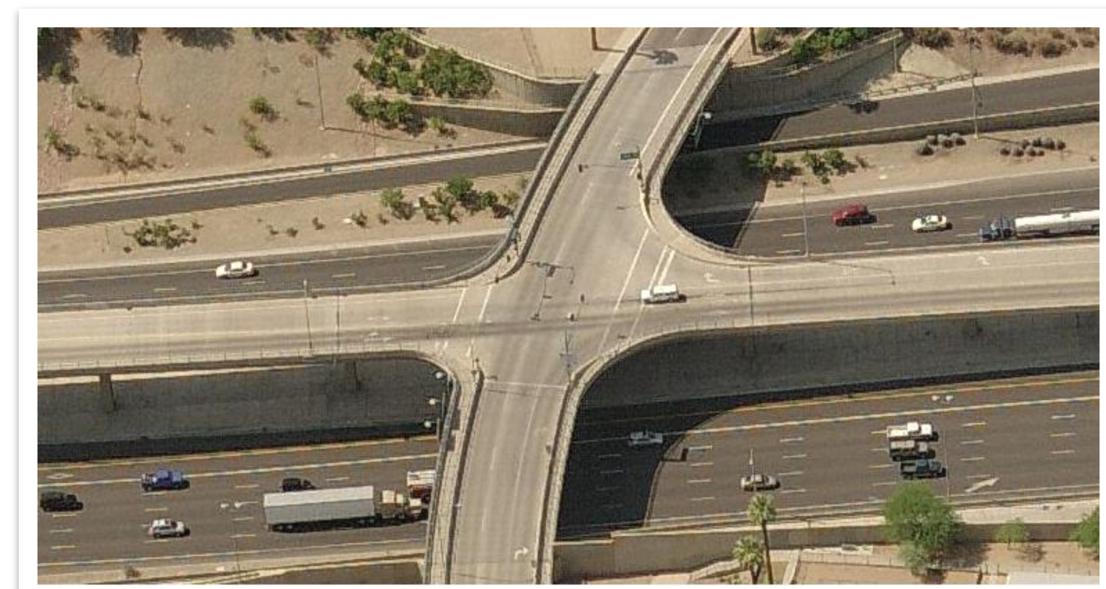
One option for the railroad bridge could utilize precast/prestressed concrete AASHTO Type IV and Type V girders. A possible span arrangement of 120'+80'+90'+90' will provide adequate lateral clearances at both the railroad and at US 180.

According to the BNSF design guidelines, cast-in-place construction over the tracks is prohibited; however, a structure that combines precast members over the existing tracks and cast-in-place construction outside the track limits could be used to "extend" clear span openings with standard precast members.

A possible structure type for the mainline I-40 bridge is a four-span precast/prestressed concrete AASHTO Type V girder bridge. Type V girders can accommodate spans up to 120 feet and will provide adequate lateral clearance from the roadway to the bridge substructure elements. A possible span arrangement of 100'+82'+100'+100' would provide adequate mainline clear zones for the median substructure elements.

Because of limited R/W on the north and the adjacent mainline to the south, the westbound ramps must be constructed either on fill using retaining walls or as bridges. At the intersection of the ramps and the cross road bridges, the ramps will be nearly 30 feet high. Options utilizing the same precast/prestressed concrete AASHTO Type V girder for the railroad bridge and the mainline I-40 bridges could be constructed easily within the available space between I-40 and the railroad R/W. Both ramp bridges would be approximately 1000 feet long and could use single column piers on drilled shafts or spread footings. The westbound entrance ramps must cross an existing access road that crosses under the I-40 mainline through equipment passes. The bridge option easily accommodates the equipment pass without special wall foundation design or equipment pass extension.

This option utilizes an elevated "central pier" or "pier table" constructed at the intersection of the four bridges. The elevated central pier could be a cast-in-place post-tensioned concrete pedestal providing bearing locations for the opposing railroad bridge and the I-40 mainline bridge and the two opposing ramp bridges. It also eliminates very tall abutments at the intersection of the bridges, similar to the two intersecting bridges shown in the photos below.

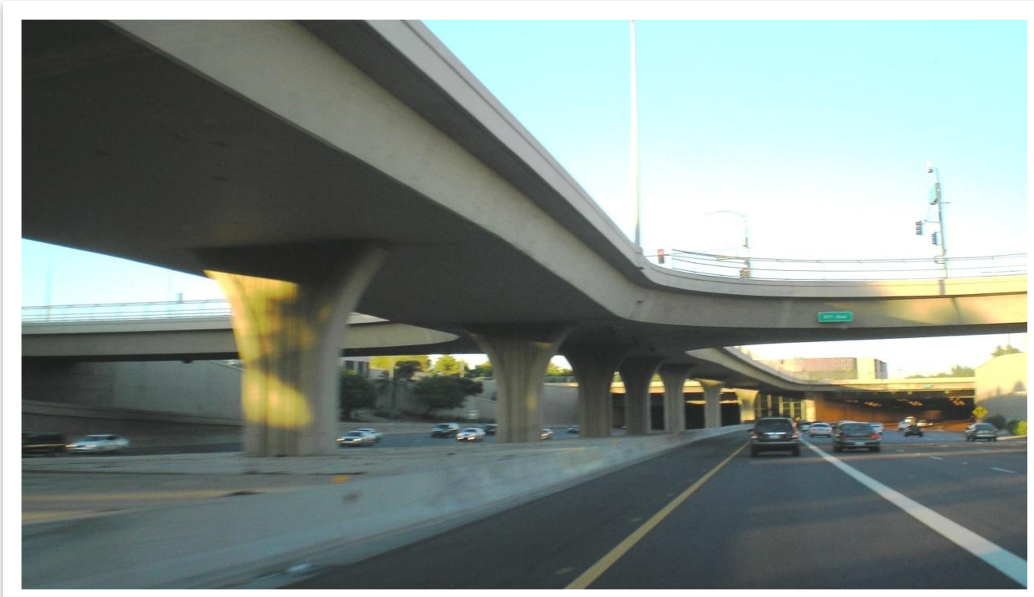


Photograph 4-10. Example of Intersecting Bridges – Overhead View.
Photo Source: Bing Maps

Other possible structure types and configurations considered include:

- Reducing bridge span lengths at the ramps to reduce reactions at the central pier.
- Eliminate the elevated central pier and design the railroad bridge and the I-40 mainline bridge as a single structure with a span of the bridge designed to accommodate the westbound ramp tie-in on each side.

- Design the central pier as a solid earth filled central abutment structure enclosed by walls rather than an elevated pier table on concrete columns.



Photograph 4-11. Example of Intersecting Bridges.

Bridge Anti-icing Technology

The bridges within the project corridor are located at elevations ranging between 6300 and 7300 feet. The surface temperature of a bridge deck will closely follow the surrounding air temperature since the undersides are open to air circulation. These factors lend themselves to ice formation on the bridges during the winter storm season. As a result, a system may be required to prevent ice from forming on some bridges within the corridor.

Research into available anti-icing technologies suggests performing an in-depth benefit/cost analysis when considering the use of anti-icing systems. There are reactive and proactive methods for dealing with the ice formation on bridge decks. A reactive approach is to dispatch maintenance crews to bridge sites during cold weather events to apply anti-icing agents or materials to improve traction (e.g., sand). A proactive approach has a system in place to monitor the bridge deck and automatically takes measures to eliminate the formation of ice on the bridge. Throughout the world there are various systems in use that employ reactive, proactive or a combination of these methods to combat the formation of ice on bridge decks.

Chemical anti-icing systems involve early application of deicing chemicals to a bridge deck to prevent freezing precipitation from adhering to the surface. Known as Fixed Automatic Spray Technology (FAST), and used in conjunction with Roadway Weather Information System (RWIS), in-place sensors and mechanical spray systems monitor and apply a chemical anti-icing agent which prevents bonding between a bridge deck and snow or ice. The chemicals used are typically salt-based solutions: sodium-chloride and calcium chloride. However, these chemicals are known to cause corrosion to bridge decks and steel components as well as being harmful to plant life when used in high concentrations. New deicing chemicals such as calcium magnesium acetate have become more accepted because it is noncorrosive to bridge decks, steel and aluminum and is more environmentally friendly.

Thermal anti-icing systems for bridge decks prohibit the buildup of ice and snow within the travel lanes. Existing types of heating bridge decks include:

- Hydronic systems pump heated fluid through pipes embedded in a continuous loop near the surface of the bridge deck. The fluid warms the bridge deck through conduction and prevents the buildup of ice and snow, the cooled fluid is returned to the heat source and the cycle is repeated.
- Heat pipes use a working fluid that is vaporized by a heat source at one end of a structure and travels through pipes either embedded in the bridge deck, or mounted to the underside of the deck and insulated. The heated vapor exchanges its heat with the bridge deck and condenses back to a liquid state at the other end. The liquid is then collected and pumped back to the heat source where the cycle is repeated.
- Electrical deck heating uses electrical resistance within conductors in the pavement to produce heat, similar to radiant floor heating installed in homes. Grids of wire mesh can be embedded into the bridge deck or a new technology can be employed that uses electrically conductive concrete to heat bridge decks.

Specialized Pavements and surface overlays have been developed in recent years that can substantially reduce or eliminate the formation of ice on bridge decks and roadways. When anti-icing agents are applied to these pavements, they have the ability to "soak up" and store the chemical agent. During winter weather conditions, the anti-icing agent is "released" or activated to prevent ice and snow buildup on the pavement. Tests have shown that anti-icing agents can be applied up to two days before a winter storm is expected. When a specialized pavement or surface overlay is used in conjunction with pavement sensors and Intelligent Transportation Systems (ITS), a system can be created that will provide maintenance crews the ability to monitor bridges susceptible to ice formation and act accordingly.

Use of a specific bridge type may also offer some protection from ice formation due to inherent insulating properties. A box girder bridge, for example, prevents free air circulation at the underside of the bridge deck due to the large hollow air space between the deck and the soffit. This type of structure could provide some insulating properties and, if used with specialized pavements, may offer a cost-effective method of mitigating ice formation on the bridge deck.

Table 61 lists possible anti-icing systems for consideration.

Table 61 – Anti-Icing Systems

ICE PREVENTION METHOD	COST	ADVANTAGES	DISADVANTAGES
Fixed Anti-icing Spray Technology (FAST) System	≈ $25 per sq ft	Fully automated, real time monitoring and data collection capabilities	High cost, complicated, requires regular upgrades and maintenance, could pose environmental concerns
Thermally Heated Deck System	≈ $25-$75 per sq ft	Fully automated, real time monitoring and data collection capabilities	High cost, complicated, requires regular upgrades and maintenance, could pose environmental concerns
Specialized Pavement, Sensors & Monitoring	≈ $8 per sq ft	Simple, easier to implement, low initial cost	Reactive - requires special equipment for application of anti-icing chemicals
Bridge Superstructure Type	Varies by Bridge Size	Box structure may provide some protection from deck freezing	Construction could be a challenge at canyon locations, benefits are unproven
Manual Chemical Application	≈ $0	No initial capital costs	Reactive - requires maintenance crews for application of anti-icing chemicals, could pose environmental issues

Many factors affect the choice of an anti-icing system, including cost, location, maintenance requirements, duration and number of storms events, accidents, and environmental concerns. Since the construction date of bridge replacement within the corridor is unknown, it will be essential to investigate state-of-the-art and costs of anti-icing technology available at that time. Based on 2009 dollars, the initial cost of an anti-icing system can range from about $8 per square foot for specialized pavements to an average of $50-$75 per square foot for fully automated systems. It is recommended that anti-icing measures be considered at new or replacement bridge locations and a complete benefit/cost analysis be performed as part of the final design to determine the appropriate anti-icing system for these bridges.

4.14.2 Retaining Walls

The mainline profile will be raised between stations 1785+00 and 1830+00 (MP 188.18 to MP 189.03). Retaining walls will be required to prevent the resulting fill slopes from encroaching onto the adjacent BNSF R/W, which is only 35 feet from the edge of roadway in some areas. Wall heights will vary along this section from a minimum of 4 feet to a maximum of 20 feet. A special roadway barrier design is required for barrier adjacent to this retaining wall. Space limitations between the edge of roadway and the retaining wall do not permit the use of standard guardrail or roadway barrier. Construction of these walls may require temporary construction easements (TCEs) at some locations due to the close proximity of the railroad R/W.

At the Riordan railroad OP, the close proximity of the west bridge abutments to the tracks may require retaining walls to prevent the abutment foreslopes from encroaching onto the railroad R/W. Final wall heights and lengths will depend on the location and type of bridge abutments determined during final design.

At the new US 89 TI, the westbound ramps will require retaining walls. The tight diamond configuration requires that the westbound entrance and exit ramp alignments be close to the widened westbound mainline alignment. The majority of the ramps will be on structure; however, retaining walls are proposed at the mainline connection. Similar to the eastbound mainline retaining wall, special concrete barrier will be constructed at the wall locations on the westbound ramps at the new US 89 TI. Construction of these walls may require TCE's at some locations due to the close proximity of the railroad R/W.

4.14.3 Noise Barriers

The preliminary noise technical study recommends potential noise mitigation at several locations along the I-40 corridor. Noise mitigation, if approved, would likely be accomplished in the form of a wall. Preliminary noise barrier recommendations are reflected on the plan sheets in Appendix C and in the cost estimate. Several areas adjacent to planned developments will be further analyzed when more information about the developments is available. Noise barrier recommendations will be evaluated and finalized during the final design of the project.

4.14.4 Pipes and Box Culverts

There are numerous locations where pipes and box culverts cross I-40 within the project corridor, of which ten appear on the ADOT Bridge Inventory. The latest available inspection reports from 2006 and 2010 for these structures reflect sufficiency ratings between 82.13 and 97.19. The proposed mainline profile changes do not appreciably affect the amount of fill over these pipes and box culverts and do not exceed the original soil cover design height. Because of the widened roadway cross section, all of the structures will need to be extended.

4.14.4 Equipment Passes

It will be necessary to extend the lengths of existing equipment passes within the project corridor due to the widening of new mainline roadways. Changes to the mainline profile do not substantially affect the amount of fill over the buried structures. However, at some locations where shallow cover over an existing structure is combined with the extended mainline cross slope, a conflict may arise between the roofs of the boxes and the mainline pavement section. These conflicts will be addressed during final design. ADOT standard equipment pass structures do not appear on the ADOT Bridge Inventory because the span lengths are less than 20 feet. Equipment pass modifications have been addressed and quantified as part of the drainage section of this report.

4.15 Preliminary Pavement Design

Subgrade conditions through the project area are anticipated to be suitable; however, there is a concern for freeze/thaw cycle damage and some subgrade improvements will likely be required. There is some potential for the presence of high plasticity soils in areas underlain by basalt and sedimentary deposits, where local treatments including overexcavation and replacement may be necessary.

Preliminary pavement designs were developed by ADOT Materials Group. The pavement design year is 2040. The results of the analyses are summarized in Table 62.

Table 62 – Preliminary Pavement Structural Section Recommendations

LOCATION	WIDENING OR RECONSTRUCTION	REHABILITATION (FULL WIDTH)	
		MILL	REPLACE
MP 183.0 to MP 190.8 Eastbound and westbound	½" AR-ACFC 12" AC 18" AB	½"	½" AR-ACFC 2 ½" AC
MP 190.8 to MP 195.0 Eastbound	½" AR-ACFC 12" AC 6" PBTB 6" AB	½"	½" AR-ACFC 3" AC
MP 190.8 to MP 195.0 Westbound	½" AR-ACFC 12" AC 6" PBTB 6" AB	5"	½" AR-ACFC 5" AC
MP 195.0 to MP 202.3 Eastbound and westbound	1" AR-ACFC 14" Dowelled PCCP 4" PBTB 4" AB		
MP 202.3 to MP 214.0 Eastbound and westbound	½" AR-ACFC 12" AC 12" AB	3"	½" AR-ACFC 3" AC
Ramps and Cross Roads Urban Rural Heavy Truck Traffic	1" AR-ACFC 10" PCCP 4" AB		
Ramps and Cross Roads Rural	½" AR-ACFC 5" AC 8" AB		

Rio de Flag structures exception: Mill and replace 1" AR-ACFC full width EB MP 197.08-197.95 and WB MP 196.83-197.74
AR-ACFC exception: All cross roads and ramps 300 feet from ramp/cross road intersections

An AR-ACFC surface course measuring ½-inch thick is recommended for flexible pavement and one inch for PCCP.

4.16 Flagstaff Urban Trail System

The FUTS is a citywide interconnecting network of non-motorized transportation corridors and linear recreation areas. The trail system crosses I-40 in numerous locations. Where possible, the trail crossings use bridges to cross over I-40. At other locations, the trail system utilizes equipment passes and box culverts to cross beneath the freeway.

Table 63 lists the existing and proposed trail crossings of I-40, locations, sizes, and a "comments" column to describe actions by ADOT or by others to accommodate the trails unless they are not recommended.

An existing 6'x7' concrete box culvert has been used as an un-permitted trail crossing of westbound I-40 at approximately MP 197.0. This crossing has been fenced off by ADOT to exclude trail users from the median area between the westbound and eastbound roadways. Because the fencing has been cut by trail users and because the box culvert outlets into a detention basin that is unsuitable for trail users, it is recommended that permanent gates be installed on both ends of the culvert. Alternate access to the Rio de Flag trail is accessible on the northeast side of the neighborhood immediately north of the box culvert.

Table 63 – Recommendations for FUTS Crossings

I-40 TRAIL CROSSINGS						RECOMMENDED DESIGN CONCEPT				
Trail Name	Milepost	Existing	Planned	Over/Under I-40	Crossing Structure	Remain in place	Not recommended	Design now	Design future	Comments
Santa Fe West Trail	192.6		X	Under	Flagstaff Ranch TI	X				Widened I-40 bridges will not preclude future trail construction. If bridges are replaced in the future, longer spans may be considered to accommodate desirable trail dimensions.
Woody Mountain Trail	193.5		X	Over	New Woody Mtn TI			X		New Woody Mountain TI bridges will include trail crossing on structure.
Southwest Crossing Trail	194.7	X		Under	16'X14' CBCs	X				I-40 widening will extend existing CBCs; existing trail to remain. May need to replace fencing to control access in median with mainline widening.
Sinclair Wash Trail	195.3	X		Under	SR 89A OP	X				I-40 bridge replacements will be designed to accommodate current trail configuration.
Lone Tree Trail	196.2	X		Under	Lone Tree OP	X				I-40 bridge replacements will be designed to maintain similar trail characteristics.
New Lone Tree Trail	196.5		X	Over	New Lone Tree TI UP			X		New Lone Tree TI will include trail crossing on cross road.
Arroyo Trail	197.0		X	Under	6'X7' CBC, WB only		X			I-40 improvements will limit culvert use to stormwater only. Recommend that trail users be routed to existing crossings to the east.
Sinclair Wash Trail	197.5	X		Under	Rio de Flag Bridge	X				Widening of Rio de Flag bridges will be designed to accommodate existing trail to remain.
Arizona Trail	197.7	X		Under	20'X13' CBC, WB only	X				I-40 widening will extend existing CBC; existing trail to remain.
Switzer Wash Spur	199.0		X	Under	2-10'X8' CBCs				X	I-40 widening will require CBCs to be connected in median. New total length would be 430 feet. Median grate openings could be used to provide natural light at midpoint of culvert crossing in I-40 median.
Fourth Street Trail	199.3		X	Over	Fourth St. UP				X	New Fourth Street UP structures should be designed to accommodate planned trail crossing.
Country Club Trail	201.1		X	Over	Country Club TI			X		Widened Country Club UP structure will be designed to accommodate planned trail crossing.
Walnut Canyon Trail	201.9		X	Under	12'X10' CBCs				X	I-40 widening will extend existing CBCs. Add fencing to control access in median and from I-40 roadways to R/W fences.
Flagstaff Loop Trail	204.3		X	Under	12'X12' CBCs				X	County to permit and maintain trail; not part of FUTS and no encroachment permit from ADOT. Design to USFS standards. I-40 widening will extend existing CBCs.
Arizona Trail	206.7	X		Under	10'X10' CBCs	X				I-40 widening will extend existing CBCs. Trail not part of the FUTS. No current encroachment permit from ADOT.

Notes:
Remain in-place = I-40 improvements will not affect existing or planned trail.
Not recommended = I-40 improvements will not affect trail; however, trail crossing is not recommended.
Design now = I-40 improvements will affect trail crossing; modifications can be accommodated with I-40 project(s).
Design future = I-40 improvements will affect trail crossings; address with future project(s).

4.17 AZPDES Permit

Any construction project that will disturb one or more acre of land will require an Arizona Pollution Discharge Elimination Systems (AZPDES) general permit as directed by Section 402(p) of the Clean Water Act. The implementation plan section (to be prepared at a later phase of the study) will describe recommended construction segments and discuss the need for AZPDES permits.

4.18 Construction Water Sources

The construction cost estimate assumes 70 gallons of water will be required per cubic yard of material. A source of construction water has not been identified.

4.19 ITS / Incident Management

4.19.1 Introduction

ADOT's ITS requirements are outlined in ADOT's research report, *ITS Concepts for Rural Corridor Management*, September 2007. Section 3.1.1 of the report outlines the ADOT Flagstaff District's main traffic management concerns. These include accurate weather forecasting, real-time traffic monitoring, coordination with other agencies on interstate closures, ITS maintenance funding, bridge deck icing, and wildlife collisions. The most important of the five project issue areas for the District are ITS maintenance and weather forecasting. The least important issue is motorist assist patrols.

The vision for the ADOT Flagstaff District is to have a fully-automated communication system to alert motorists to hazardous conditions, including icy road surface conditions, low visibility conditions, rockslide events, wildlife presence, and severe weather conditions.

Section 3.2, Table 4, "Districts Needs Matrix," details what ITS components are identified as major or minor needs. Mentioned, but not covered under the types of devices, was the District's desired installation of wildlife detection and monitoring systems.

The specific needs identified by the ADOT Flagstaff District that relate to the I-40 corridor are:

- Chemical Application Rate Monitors for Plows
- Snow Plow Simulator Training
- Real Time Traffic Monitoring (I-40)
- Closed Circuit Television (CCTV) Monitoring
- Procurement or Leasing of ITS with Full Maintenance & Support
- Budgetary Funding for ITS Maintenance
- Wildlife Presence Detection
- Reduced Night Time Speeds
- Weather Forecasting Services
- Low Cost Weather Sensors
- Additional Roadway Weather Information Sites
- Portable Roadway Weather Information technology
- Bridge Deck Icing Monitors
- Fog Warning Advisories
- Additional Dynamic Message Signs (DMS)
- Good DMS Maintenance Service
- Multiple Agency Coordination for Traveler Information and Incident Response
- Comprehensive AZ 511 System
- Highway Advisory Radio for Work Zones
- Highway Advisory Radio for Port of Entry and Rest Areas
- Highway Advisory Radio for Rock Slide Hazards

While many of these ITS needs are beyond the scope of this DCR, it is important to include a description or vision of the fully evolved ITS system so that ITS infrastructure elements can be included in future projects that will contribute to ADOT's long-term traffic management goals.

4.19.2 Recommended ITS Elements

The recommended ITS elements for the corridor are based on the ITS needs identified by ADOT Transportation Technology Group and the Flagstaff District. The primary elements include:

- Real Time Traffic Monitoring of I-40
- Comprehensive CCTV Coverage
- DMS
- ITS Communications
- Traveler Information Systems
- Roadway Weather Information Applications
- Wildlife Presence Detection
- Bridge Deck Icing Detection and Warning System

Real Time Traffic Monitoring

Real time traffic monitoring is an important ITS element for incident detection and travel time data. Vehicle detection technology has evolved considerably over the past 20 years with the increase use of video, acoustic and other non-intrusive detection devices. However, some of these detection technologies have not proven to be as accurate as loop detectors under certain conditions. Other in-pavement or under pavement detection devices are also being tested by ADOT. Some of these technologies include wireless communications from the detector to the cabinet and from the cabinet to a communications hub.

Other systems have also been developed that use inductance footprint matching that can track vehicles throughout a corridor to provide very accurate travel time information, as well as the traditional spot speed and density data. Some private vendors have also developed systems that can report travel time data using a large pool of probe vehicles.

As detection technology continues to evolve, one or more of these "state-of-the-art" technologies may emerge as the preferred form of detection at the final design stages for ITS in this corridor.

The infrastructure envisioned to provide real time traffic monitoring capability includes vehicular detectors every mile, capable of providing speed, density, travel time information and permanent count stations located between every traffic interchange.

CCTV Monitoring

CCTV cameras will be an important ITS element for accurate verification of incident location and type. This information is critical for appropriate and timely incident response. CCTV cameras should be installed to provide full coverage of the corridor within the project limits. CCTV cameras are typically installed at one-mile spacing within the urban freeway corridors. It may be possible to place the cameras at a greater spacing with camera locations that take advantage of favorable look-out locations. For estimating purposes, a camera spacing of two miles has been assumed. Cameras are recommended at the following locations:

1. New Camp Navajo TI
2. Bellemont TI
3. A-1 Mountain TI
4. Flagstaff Ranch TI
5. I-40/I-17 System TI
6. Butler TI
7. Country Club TI
8. Walnut Canyon TI
9. Cosnino TI
10. Winona TI

These cameras should be located to allow traffic operations personnel to view the merge-diverge areas and the DMS messages at these locations. Specific camera locations that provide full coverage of the corridor should be identified during final design. ADOT has typically used a barrel type pan-tilt-zoom camera with an AC power source. Electrical power will be available at most of the locations listed above.

The availability of AC power throughout the corridor may be problematic. The power demand of the camera control and communications equipment makes the use of a solar charged DC power source problematic as well. Surveillance cameras are now being manufactured that use a hemispherical lens that can provide a 360-degree view without the need to mechanically pan or tilt the camera. This type of technology may make solar power more viable. Solar charged DC power may also be more viable in the future as solar and battery technologies continue to improve. Camera type, communications needs, and power sources need to be evaluated during the final design stage to identify the best CCTV camera solution for this corridor.

DMS Locations

DMS boards are an important Traveler Information System device to support incident management and communicate travel time information. There are existing DMS boards within the project limits in the following locations:

- Eastbound I-40, MP 185.5
- Eastbound I-40, MP 199.8
- Westbound I-40, MP 212.1

There are also existing DMS boards west of the project limits at eastbound MP 168.0; east of the project limits at eastbound MP 250.7; and south of the project limits at southbound I-17, MP 337.9.

Based on the expected improvements to I-40 identified in this DCR, additional DMS boards are recommended at the following locations:

1. Eastbound I-40, MP 189: one mile in advance of the West Flagstaff TI
2. Eastbound I-40, MP 193: two miles in advance of the I-40/I-17 system TI
3. Eastbound I-40, MP 200: one mile in advance of the new US 89 TI
4. Westbound I-40, MP 204: two miles in advance of the new US 89 TI
5. Westbound I-40, MP 197.5: two miles in advance of the I-40/I-17 system TI
6. Westbound I-40, MP 193: between the new Woody Mountain TI and the Flagstaff Ranch TI

These sign locations will provide travelers with enough notice to select an alternative route based on the latest travel time and incident information, as well as alert drivers of adverse weather conditions. Six to ten additional DMS boards are recommended outside the project limits to redirect traffic from the I-40 corridor to other routes such as SR 87, SR 260, SR 89A, SR 64, US 180, US 93, and US 89 when road closures or long delay conditions occur.

ITS Communications Infrastructure and Power Distribution

The ITS infrastructure should be a comprehensive communications system that is composed of an integrated fiber optic cable, cell phone, and radio communications system. The system should provide communications from all field equipment to the ADOT Phoenix Traffic Operations Center as well as to the future ADOT Traffic Operations Center in Flagstaff. The backbone of this system will be 3-3" conduits throughout the project. The fiber optic backbone should consist of two 144 strand fiber optic cables and major nodes or communications hubs located near:

- West Flagstaff TI
- New US 89 TI

The Initial DCR for I-17, Jct. SR 179 to I-40, anticipated early 2010, recommends a major node or communications hub at the I-40/I-17 system interchange. These super nodes should include towers for wireless communications.

This fiber and wireless infrastructure is envisioned to be part of a larger, District and ADOT-wide communications system that will be integrated with the existing ADOT and Department of Public Safety microwave communications system. The fiber and wireless components should be a part of the roadway project construction to ensure the communications with remote video, DMS and detector stations are integrated with the other landline and hardwired ITS facilities.

The communications system may also include cell phone or radio communications links to devices located along the corridor. For example, the video, DMS and detectors may be connected directly to the fiber communications network while some of the video and detector stations could be wireless links to the fiber optic backbone.

The Transportation Technology Group has expressed the desire that all devices in the corridor be Internet-protocol addressable. The final design communications system should be developed for the entire corridor, taking into consideration phased construction of the projects within the corridor.

Other Traveler Information System Technologies

Traveler information systems come in many forms. It is envisioned that one or more of the ITS capabilities included in the recommended project will require an expansion and refinement of the ADOT Traveler Information System including extensive use of the AZ 511 System, an improved Highway Advisory Radio (HAR) system, improved travel information distributed to television and local radio stations, and long term expansion of on-board travel time information. ADOT is currently using HAR to provide information to the public regarding major construction projects. The ADOT Communications and Community Partnerships office which is responsible for public and media outreach is a good resource to assist with the preparation of clear and concise messages. These systems will be particularly important during the construction phases of the various projects in this corridor.

Roadway Weather Information Applications

The ADOT report *ITS Concepts for Rural Corridor Management*, September 2007, shows one RWIS within the study area. The report indicates nearly all the districts would value data supplied by RWIS. However, problems with reliability and maintenance of the existing systems have been an ongoing concern for ADOT. Quixote Corporation is currently under contract to maintain the existing sites and provide weather data to ADOT. The reliability and cost effectiveness of this service will be an important factor in the decision to expand the existing network of RWIS applications.

The installation of a RWIS to detect snow, ice, and fog within the study corridor should be evaluated during the final design stage, in coordination with the Transportation Technology Group and the ADOT Flagstaff District office.

Wildlife Presence Detection

Several recently-constructed wildlife presence detection system projects are currently being evaluated by ADOT and AGFD. AGFD has ongoing research within the project limits regarding potential wildlife crossings and will assist the study team in developing specific wildlife crossing recommendations for the recommended alternatives. These recommendations should be reviewed with respect to any wildlife presence detection systems that should be included in the overall ITS plan within the project limits.

Bridge Deck Icing Detection and Warning System

The most effective method to address this issue is detection and de-icing technology. This system will eliminate the potential hazard rather than strictly warn of the hazard only. Bridge ice detection and de-icing systems are typically incorporated into the bridge design. A discussion of this issue is included in the bridge design section of this report. The communications component of the ice detection and de-icing system should be incorporated into the overall ITS communications system. Advance warning signs can also be incorporated into the bridge de-icing system. However, it has been found that these warnings can be an unnecessary distraction to drivers and a source of confusion regarding proper driver response. Dynamic advance warning signs regarding generally icy or poor weather conditions should be incorporated into the bridge icing detection system design, without specific focus on the conditions on the bridge.

4.20 Traffic Interchange Lighting

Section 3.2 of the AASHTO *Roadway Lighting Design Guide*, October 2005, describes the warranting conditions for the installation of fixed lighting for roadways. The warrants are a guideline for establishing a basis on which lighting for freeways may be justified or recommended. The warrants provide minimum conditions to be met whenever an agency is contemplating lighting. Meeting the warrants does not obligate the agency to provide lighting. Freeway lighting provides a number of benefits to motorists, which include improving the ability to see roadway geometry, objects in the roadway, and other vehicles at extended distances ahead. Each interchange within the project limits was evaluated for the installation of complete (full) interchange lighting (CIL), as well as partial interchange lighting.

The design requirement for light level is 0.6 foot-candles. Full cutoff fixtures with high-pressure sodium lamps should be used to comply with dark sky requirements and match the existing lighting at the I-17 / I-40 system traffic interchange. Current practice for lighting in ADOT's Northern Region is to limit the mounting height to 35 feet due to the limitations of existing maintenance equipment. The widening of I-40 may necessitate higher mounting heights and/or lighting installed on median barrier to achieve minimum design criteria.

CIL consists of a lighting system that provides relatively uniform lighting within the limits of the interchange, including the main lanes, ramp terminals and the cross road intersection. The CIL warrants shown in Table 64 are a function of the ADT. The first warrant (CIL-1) is met if the total ADT entering and leaving the ramps within the interchange exceeds 5000 vehicles per day (vpd), and the second warrant (CIL-2) is met if the ADT on the cross road exceeds 5000 vpd. The traffic volumes used in this evaluation were the 2040 forecasted AADT.

Partial interchange lighting (PIL) is a lighting system that provides illumination only at decision-making areas, which include ramp intersections. The PIL warrants shown in Table 64 are also a function of the projected ADT. The first warrant (PIL-1) is met if the total ADT entering and leaving the ramps within the interchange exceeds 1000 vpd, and the second warrant (PIL-2) is met if the ADT on the freeway through traffic lanes exceeds 10,000 vpd.

The Flagstaff District uses a “hybrid” lighting design for interchanges that experience high volumes. With the hybrid lighting design, interchange gores, ramps, ramp terminals, and the cross-road are all lit; however, the mainline is not lit.

Table 64 – Traffic Interchange Lighting Warranting Conditions

	COMPLETE INTERCHANGE LIGHTING (CIL)		PARTIAL INTERCHANGE LIGHTING (PIL)	
	TOTAL ADT RAMP TRAFFIC ENTERING AND LEAVING THE FREEWAY WITHIN THE INTERCHANGE AREA EXCEEDS 5,000 FOR RURAL CONDITIONS	TOTAL ADT ON THE CROSS ROAD EXCEEDS 5,000 FOR RURAL CONDITIONS	TOTAL ADT RAMP TRAFFIC ENTERING AND LEAVING THE FREEWAY WITHIN THE INTERCHANGE AREA EXCEEDS 1,000 FOR RURAL CONDITIONS	ADT ON THE FREEWAY THROUGH TRAFFIC LANES EXCEED 10,000 FOR RURAL CONDITIONS
TRAFFIC INTERCHANGE	CIL-1	CIL-2	PIL-1	PIL-2
New Camp Navajo TI	YES	YES	YES	YES
Bellemont TI	YES	YES	EXISTING PIL	
A-1 Mountain TI	NO	NO	NO	YES
West Flagstaff TI	YES	YES	EXISTING PIL	
Flagstaff Ranch TI	NO	NO	EXISTING PIL	
New Woody Mountain TI	YES	YES	YES	YES
New Lone Tree TI	YES	YES	YES	YES
Butler TI	YES	YES	EXISTING PIL	
Country Club TI	YES	YES	EXISTING PIL	
New US 89 TI	YES	YES	YES	YES

TRAFFIC INTERCHANGE	COMPLETE INTERCHANGE LIGHTING (CIL)		PARTIAL INTERCHANGE LIGHTING (PIL)	
	TOTAL ADT RAMP TRAFFIC ENTERING AND LEAVING THE FREEWAY WITHIN THE INTERCHANGE AREA EXCEEDS 5,000 FOR RURAL CONDITIONS	TOTAL ADT ON THE CROSS ROAD EXCEEDS 5,000 FOR RURAL CONDITIONS	TOTAL ADT RAMP TRAFFIC ENTERING AND LEAVING THE FREEWAY WITHIN THE INTERCHANGE AREA EXCEEDS 1,000 FOR RURAL CONDITIONS	ADT ON THE FREEWAY THROUGH TRAFFIC LANES EXCEED 10,000 FOR RURAL CONDITIONS
	CIL-1	CIL-2	PIL-1	PIL-2
Walnut Canyon TI	NO	NO	YES	YES
Cosnino TI	NO	NO	YES	YES
Winona TI	NO	NO	YES	YES

Complete interchange lighting does not exist at any of the interchanges within the study corridor. Hybrid interchange lighting exists at the following location:

- Butler TI

Partial interchange lighting exists at the following traffic interchanges:

- Bellemont TI
- West Flagstaff TI
- Flagstaff Ranch TI
- Country Club TI

Based on the CIL warrants, complete interchange lighting is warranted at the following traffic interchanges:

- New Camp Navajo TI
- Bellemont TI
- West Flagstaff TI
- New Woody Mountain TI
- New Lone Tree TI
- Butler TI
- Country Club TI
- New US 89 TI

Based on the PIL warrants, partial interchange lighting is warranted at the following interchanges:

- A-1 Mountain TI
- Walnut Canyon TI
- Cosnino TI
- Winona TI

Lighting design requirements will be determined with the final design of the project.

The I-40/I-17 system TI is currently fully lit on all ramps. Mainline I-40 is lit approximately 0.75 mile east and west of I-17, and I-17 is lit approximately 0.5 mile south of I-40 and 0.25 mile north of I-40. Any modifications to the interchange within the limit of the existing lighting should include a new lighting design to ensure that minimum levels are maintained.

The decision to provide lighting at the interchanges must also consider the potential impact the lighting may have on nearby observatories and wildlife, and the availability of power. The *Roadway Lighting Design Guide* notes that some studies have shown that nighttime lighting may affect wildlife.

4.21 Transit Considerations

From 2007 to 2010, ADOT prepared a statewide transportation plan that formulated and evaluated roadway, public transit, and rail improvements. The resulting *Building a Quality Arizona* (BQAZ) Statewide Transportation Planning Framework Program is a vision for the State of Arizona that recommends a comprehensive 2050 transportation scenario. The BQAZ plan recommends I-40 as a route for intercity buses and passenger rail.

4.22 Wildlife Connectivity

In partnership with ADOT, AGFD began work on a three-year research study in 2008 to assess elk movement patterns and distribution relative to I-40, determine the locations of high-frequency crossing zones, and assess elk permeability across the highway corridor. ADOT's Environmental Planning Group, Flagstaff District and technical disciplines, as well as FHWA, US Forest Service (USFS), AGFD, City of Flagstaff, DPS, and Camp Navajo have been working together as a technical advisory committee to address the potential for retrofitting existing I-40 bridges and box culverts as wildlife passage structures with the erection of ungulate-proof fencing. The AGFD study will provide additional information to support such efforts, as well as evaluate the effectiveness of such retrofitting should any occur within the timeframe of the research study.

The AGFD study area encompasses all of the areas along I-40 exhibiting high incidences of elk-vehicle collision. AGFD uses global positioning system telemetry and scientific methodologies to assess movements, distribution, and measure elk permeability. Elk on-board collars have been placed and will be recovered after 22 months of data collection. Periodic progress reports based on ongoing data collection have been provided to the team.

In addition to identifying wildlife corridors for potential structure locations, AGFD has provided information to ADOT and the study team regarding critical features of successful wildlife passage structures. Their information indicates elements of successful wildlife structures include openness, sight distance, and walkways with earthen surfaces.

This study includes preparation of a Wildlife Accident Reduction Study. The study will evaluate cost, R/W, and environmental impacts related to the construction wildlife crossing structures. Based on the crossing location and strike data received from AGFD and the magnitude of the cost, R/W, and environmental impacts, potential crossing locations will be prioritized.

The final recommendations for wildlife crossing structure opportunities should incorporate the GPS data collected from elk along the highway corridor. It is likely that the final data and recommendations will be available after this I-40 study is concluded to assist ADOT, FHWA, USFS, and AGFD in making final determinations about improvements related to wildlife connectivity.

4.23 Social, Economic, and Environmental Considerations

Coordination with federal, state, and local agencies and the public was conducted to obtain information about the environmental resources in the general project area. Specific information was also obtained to define the existing social, economic, and environmental characteristics of the I-40 corridor and assist the study team in identifying particular considerations for the development and analysis of alternatives. Specific mitigation measures will be identified as part of the EA and will be included in the Final DCR.