Statewide Shoulders Study

Task MPD 059-14

Final Report

August 2015

Prepared by

JACOBS

Table of Contents

List of Tables

List of Tables (Continued)

List of Figures

List of Figures (Continued)

1. Study Overview

Located adjacent to a roadway's travel lanes, highway shoulders are essential components on any road section. Highway shoulders serve several purposes:

- Creates a safe zone for vehicles to safely exit travel lanes during emergency situations
- Allows motorists an area to maneuver if they exit the travel lane
- Increases sight distance of horizontal curves
- Provides bicyclists with a safe area adjacent to vehicle travel lanes
- Increases driver's sense of safety
- Provides structural support to highway pavement
- Protects the highway surface from damage caused by water flow
- Creates a storage area during snow removal

Shoulder improvements can lead to a plethora of safety and operational improvements, such as reduction in crashes, safe pedestrian and bicycle facilities, mitigation of drainage issues, and increased roadway capacity. Potential safety hazards can occur when a vehicle leaves the travel way and there is a significant material and elevation difference between highway pavement and shoulder surfaces. This elevation difference can affect vehicle stability, reduce a driver's ability to handle the vehicle, and often cause head-on, sideswipe, rollover, and fixed object crashes. Shoulder paving is recognized as a positive countermeasure to reduce a shoulder drop-off hazard that will accommodate stopped vehicles to avoid encroachment from the travel way, facilitate maintenance work, provide access for emergency vehicles, and protect pavement structural integrity. A paved shoulder can also assist in preventing damage to the road structure caused by water infiltration and can provide motorists with a warning system when veering off the roadway (i.e., rumble strips).

Purpose and Need

With the ultimate purpose of enhancing safety and improving mobility, the *Statewide Shoulders Study* was initiated to develop a prioritized list of candidate locations for shoulder improvements. The need for this study stems directly from ADOT's desire to increase safety and mobility along the Arizona State Highway System. The project purpose is demonstrated with the following statement of need:

- **Create Methodology.** As the first statewide, shoulder improvement prioritization project conducted in Arizona, a methodology needs to be developed that utilizes available data to accurately identify deficiencies. A statewide and district-level prioritization is needed in order to appropriate limited funds for priority projects.
- **Develop List of Shoulder Improvement Locations.** Currently, there is no statewide or ADOT Engineering District-wide listing of prioritized locations for shoulder improvement projects. This document will serve as

guidance for determining priority roadway segments within each ADOT District and throughout the State that require funding.

- **Develop Feasible, Cost Effective Implementation Plan.** High priority projects need to be evaluated for feasibility and cost-effectiveness. Due to limited funding, innovative and cost effective alternatives beyond traditional pavement applications need to be explored.

Technical Advisory Committee

This study was guided by a Technical Advisory Committee (TAC). The role of the TAC was to provide technical guidance, support, advice, suggestions, recommendations, and to perform document reviews throughout the study process. TAC members included representatives from:

- ADOT Multimodal Planning Division
- ADOT Phoenix Engineering District
- ADOT Tucson Engineering District
- ADOT Prescott Engineering District
- ADOT Yuma Engineering District
- ADOT Flagstaff Engineering District
- ADOT Holbrook Engineering District
- ADOT Kingman Engineering District
- ADOT Globe Engineering District
- ADOT Safford Engineering District
- ADOT Roadway Engineering Group
- ADOT Maintenance Group
- ADOT Bridge Group
- ADOT Right of Way
- ADOT Traffic Safety Section
- Federal Highway Administration (FHWA)

2. Literature Review and Design Standards

Reviewing current practices and methodologies utilized by state Department of Transportation (DOT) agencies and relevant technical literature often provides insight into best practices that ADOT can utilize to enhance or streamline the identification and prioritization of shoulder improvement projects.

Nationally Recommended Shoulder Guidelines

The American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* provides shoulder width standards on the national level. Table 2.1 summarizes minimum shoulder width per AASHTO guidelines. The standards displayed in the table represent design values for usable and paved shoulders – usable shoulder width is the actual width utilized by motorists and is measured from the edge of the travel lane. For interstates with six or more lanes AASHTO recommends that the right shoulder width not be less than 10 feet. Additionally, AASHTO recommends a paved 12 foot right shoulder on interstates with six or more lanes and truck traffic exceeds 250 DDHV (directional design hour volume).

Table 2.1: AASHTO Shoulder Width Design Guidelines

Type of Roadway	Rural		Urban	
	US (Feet)	Metric (Meters)	US (Feet)	Metric (Meters)
Freeway	4 - 12	1.2 - 3.6	4 - 12	1.2 - 3.6
Ramps (1-Lane)	1 - 10	0.3 - 3.0	1 - 10	0.3 - 3.0
Arterial	2 - 8	0.6 - 2.4	2 - 8	0.6 - 2.4
Collector	2 - 8	0.6 - 2.4	2 - 8	0.6 - 2.4
Local	2 - 8	0.6 - 2.4	-	-

Source: AASHTO A Policy on Geometric Design of Highways and Streets

ADOT Shoulder Design Standards

Table 2.2 summarizes the minimum shoulder width per ADOT's Roadway Design Guidelines.

Table 2.2: ADOT Shoulder Width Design Guidelines

Highway Type	Paved Shoulder Width (Feet)	
	Left	Right
Controlled Access Highways		
4 lanes	4	10
6 or more lanes	10	10
Auxiliary lanes	-	10
1-lane freeway to freeway directional ramp	6	10
2-lane freeway to freeway directional ramp	4	8
1-lane and 2-lane ramps	2	8
Ramp termini at crossroad	2	2

Table 2.2: ADOT Shoulder Width Design Guidelines (Continued)

Highway Type	Paved Shoulder Width (Feet)	
	Left	Right
Non-Controlled Access Highways		
Rural multi-lane divided	4	10
Rural 2-Lane: DHV > 200 vph	-	8
Rural 2-Lane: DHV < 200 vph	-	6
Urban multi-lane divided	2	4
Urban multi-lane undivided: 5 or more lanes	-	4
Urban multi-lane undivided: 4 lanes	-	4

Source: ADOT Roadway Design Guidelines

Highway Safety Manual (HSM)

A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. The HSM provides CMFs for the widening of highway shoulder on rural two-lane roadway segments (See Table 2.3). According to the HSM, for roadways with an AADT of 400 or less, shoulder width has a small crash effect. On roadway segments with an AADT of greater than 2000, shoulder widths less than 6 FT are predicted to experience significantly more crashes than roadway segments with 8 FT shoulders.

Table 2.3: Crash Modification Factor for Shoulder Width on Rural Two-Lane Roadway Segments

Shoulder Width	Average Annual Daily Traffic (vehicle/day)		
	<400	400 - 2000	>2000
0 FT	1.10	1.10 + .00025 (AADT - 400)	1.50
2 FT	1.07	1.07 + .000143 (AADT - 400)	1.30
4 FT	1.02	1.02 + .00008125 (AADT - 400)	1.15
6 FT	1.00	1.00	1.00
8 FT of More	0.98	0.98 + .00006875 (AADT - 400)	0.87

Source: Highway Safety Manual

Note: The collision types related to shoulder width to which this CMF applies include single-vehicle run off the road and multiple-vehicle head-on, opposite direction sideswipe, and same-direction sideswipe crashes.

Standard error of the CMF is unknown.

To determine the CMF for changing paved shoulder width and/or AADT, divide the "new" condition CMF by the "existing" condition CMF.

On divided roadway segments, the HSM provides CMFs if base condition shoulders (8 FT) are reduced. Table 4.2 provides a table of the potential crash effects if right shoulder widths are reduced on divided roadway segments. As shown in the table, on divided segments a roadway segment with a 0 FT shoulder is predicted to experience 18% more crashes than a roadway segment with an 8 FT shoulder.

Table 2.4: Potential Crash Effects of Paved Right Shoulder Width on Divided Roadways

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
8 FT to 6 FT Conversion	Rural (Multilane Highway)	Unspecified	All Types (Unspecified)	1.04	N/A
8 FT to 4 FT Conversion				1.09	
8 FT to 2 FT Conversion				1.13	
8 FT to 0 FT Conversion				1.18	

Source: Highway Safety Manual
Note: Base conditions = 8 FT wide shoulders
N/A = Standard error of CMF is unknown

Bicycle and Pedestrian Shoulder Guidelines

Per the Arizona State Department of Transportation State Transportation Board's Policies, it is a policy of the Board to encourage bicycling and walking as a viable transportation mode and to actively work toward improving Arizona's transportation network to accommodate these modes. To accommodate bicycle travel, AASHTO recommends that paved shoulders be at least four feet wide – this measurement does not include the width of rumble strips.

3. Existing Conditons Assessment

Data Collection

ADOT's GIS section, Bridge group, and Traffic Records Division now manage a robust and more accurate repository of transportation databases. At the onset of the study, the study team met with the GIS Section and ADOT PM to obtain the data identified in Table 3.1. Each database was reviewed for quality and the data was adjusted where appropriate.

Table 3.1: Data Items and Sources

Dataset	Source
Shoulder Conditions - Paved shoulders - Unpaved shoulders - Guardrail - Barriers	ADOT GIS section
Accident Location Information and Surveillance System (ALISS) Crash Database	ADOT Traffic Records
Traffic volumes (AADT) - Current and past 5 years - Vehicle classification, K & D factors - Seasonal adjustment factors	ADOT GIS section
Future traffic volumes	ADOT GIS section
Functional classification	ADOT GIS section
Highway video log	ADOT GIS section
Highway centerline GPS data	ADOT GIS section
Highway log - Median type - Lane width - Grade/Terrain - Speed - Traffic Signals	ADOT GIS section
ATIS Dataset	ADOT GIS section
Statewide Transportation Improvement Program (STIP)	ADOT MPD

Table 3.1: Data Items and Sources (Continued)

Dataset	Source
Highway Performance Monitoring System (HPMS) - Beginning MP, Ending MP - Ownership - Lanes - Access Center Lane - Median and median width - Curve and Curve Length - Horizontal Alignment - Vertical Alignment - Urban and Rural	ADOT GIS section
Transportation Data Management System (TDMS)	ADOT GIS section
Bridges and Structures	ADOT Bridge Group
As-built drawings	ADOT ROW

Existing Shoulder Widths

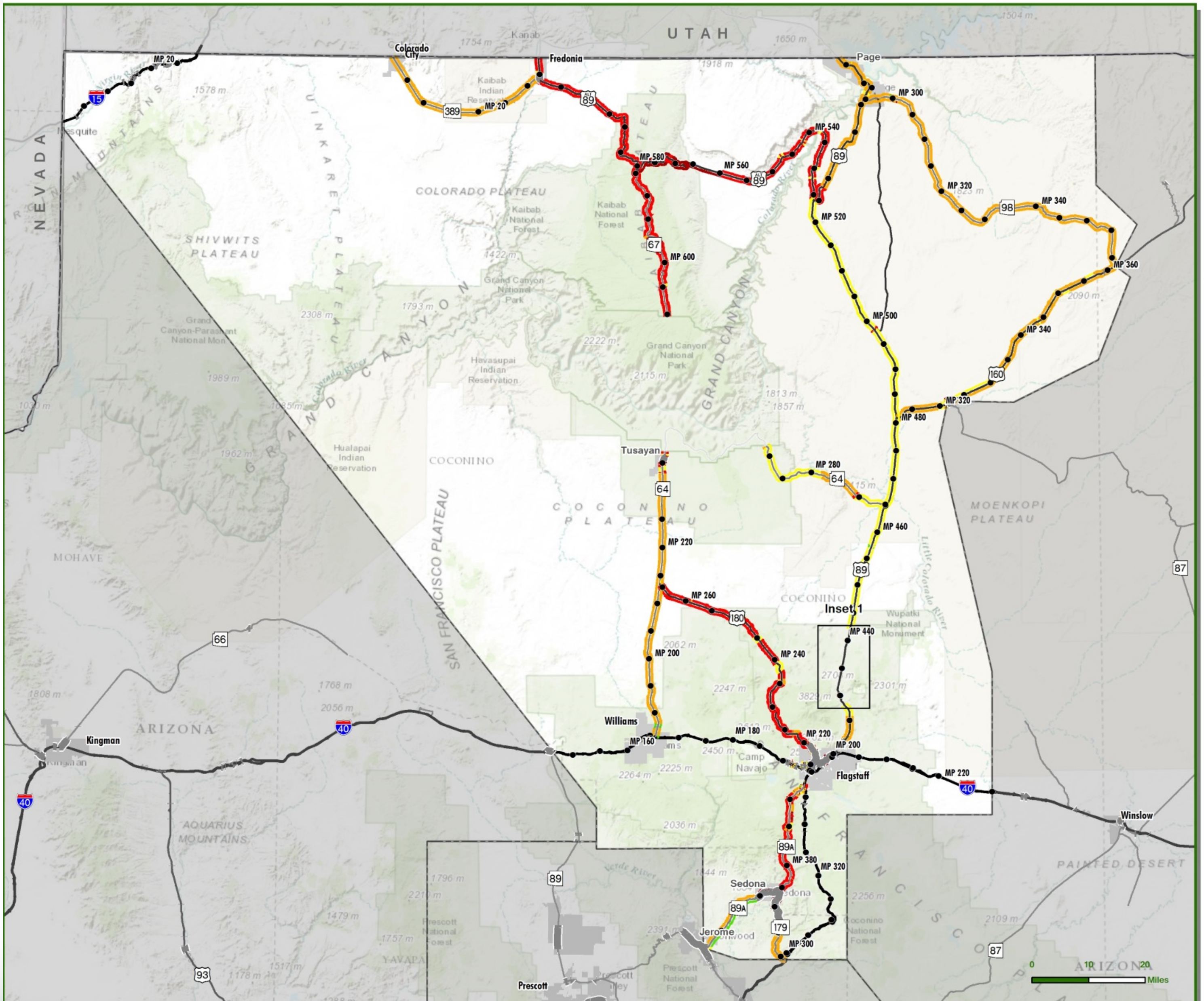
Compiling a comprehensive inventory of existing shoulder locations and conditions is an essential first step before evaluating the need for improving highway shoulders. ADOT's existing shoulder data set was used as the starting point. Verification of the shoulder width data was broken into three steps: District Engineer consultation, verification of corridors using ADOT's videolog, and finally verification of randomly selected locations based on shoulder related crash frequency using ADOT's videolog. ADOT's District Engineers have a first-hand understanding on the roadway conditions within their district. The study team met with each District to obtain feedback on shoulder width conditions based on ADOT's GIS dataset. Thirteen highway corridors were recommended by the ADOT District staff for review; and based on measurements acquired from ADOT's PhotoLog, shoulder widths were updated. Table 3.2 provides a summary of the accuracy rating of the shoulder width GIS dataset against manually acquired measurements.

Table 3.2: Manual Verification of Shoulder Width GIS Data Accuracy

Shoulder Width Range	Number of Segments Recommended for Review	Percent of PhotoLog Observations Matching GIS Data
0 FT	1	100%
1 - 2 FT	11	91%
3 - 5 FT	26	92%
6 - 8 FT	14	100%
> 8 FT	11	100%

Figures 3.1 to 3.16 illustrate the existing shoulder width conditions in each ADOT District.

Figure 3.1: Existing Shoulder Conditions - Flagstaff District



LEGEND

Shoulder Width
- 0 ft
- 1 - 2 ft
- 3 - 5 ft
- 6 - 8 ft
- > 8 ft

- Milepost
- Interstate Highways
- US Highways
- State Highways
- Curb and Gutter
- Cities/Towns
- District Boundary

Inset displays left and right shoulder widths along divided highways.

Data Source: ADOT

Inset 1 - US 89: MP 428 - MP 442

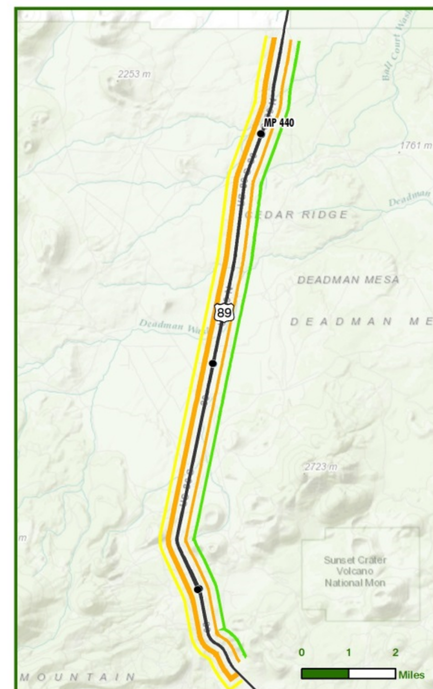


Figure 3.2: Existing Shoulder Conditions - Flagstaff District (Divided Highways)

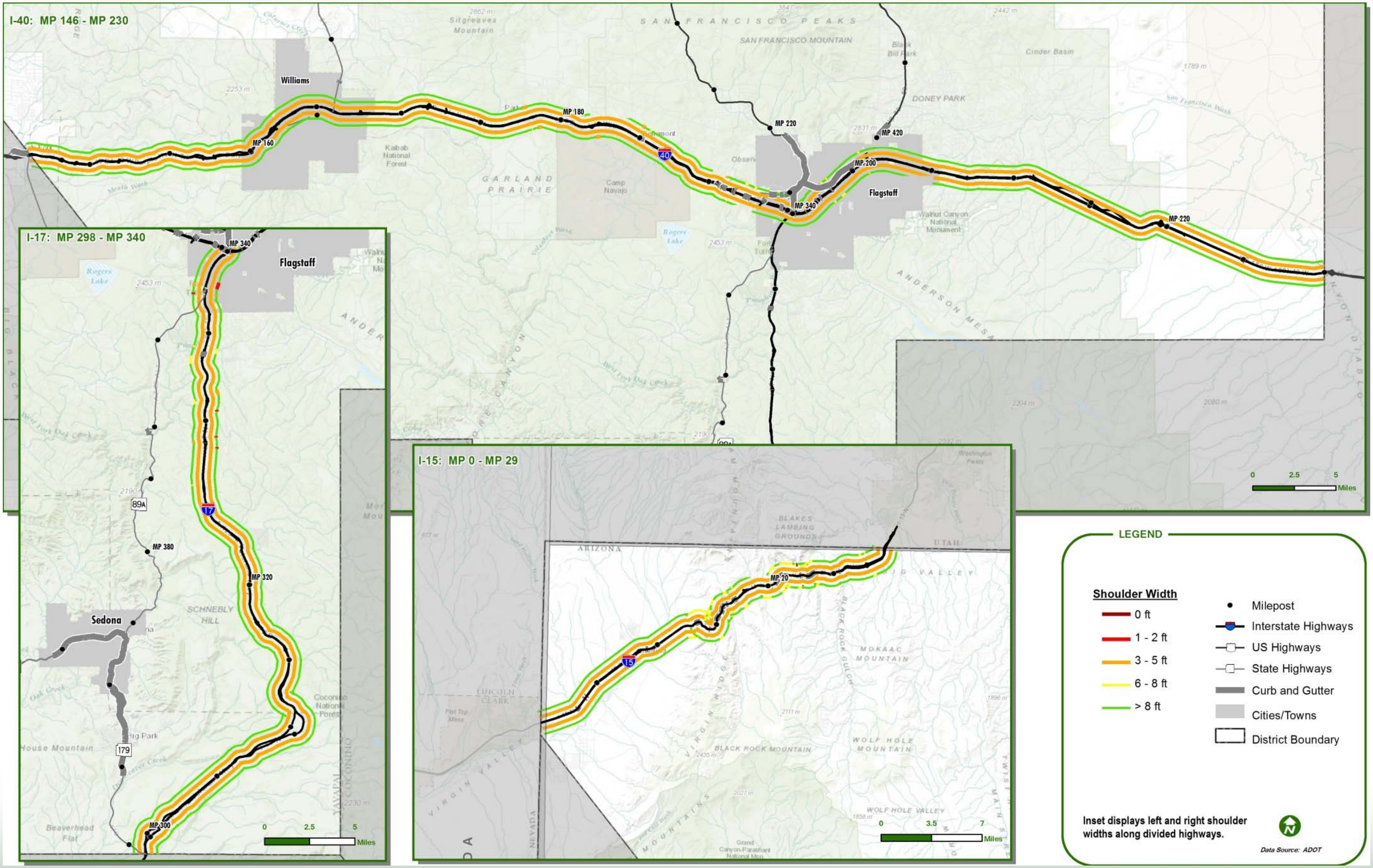


Figure 3.3: Existing Shoulder Conditions - Globe District

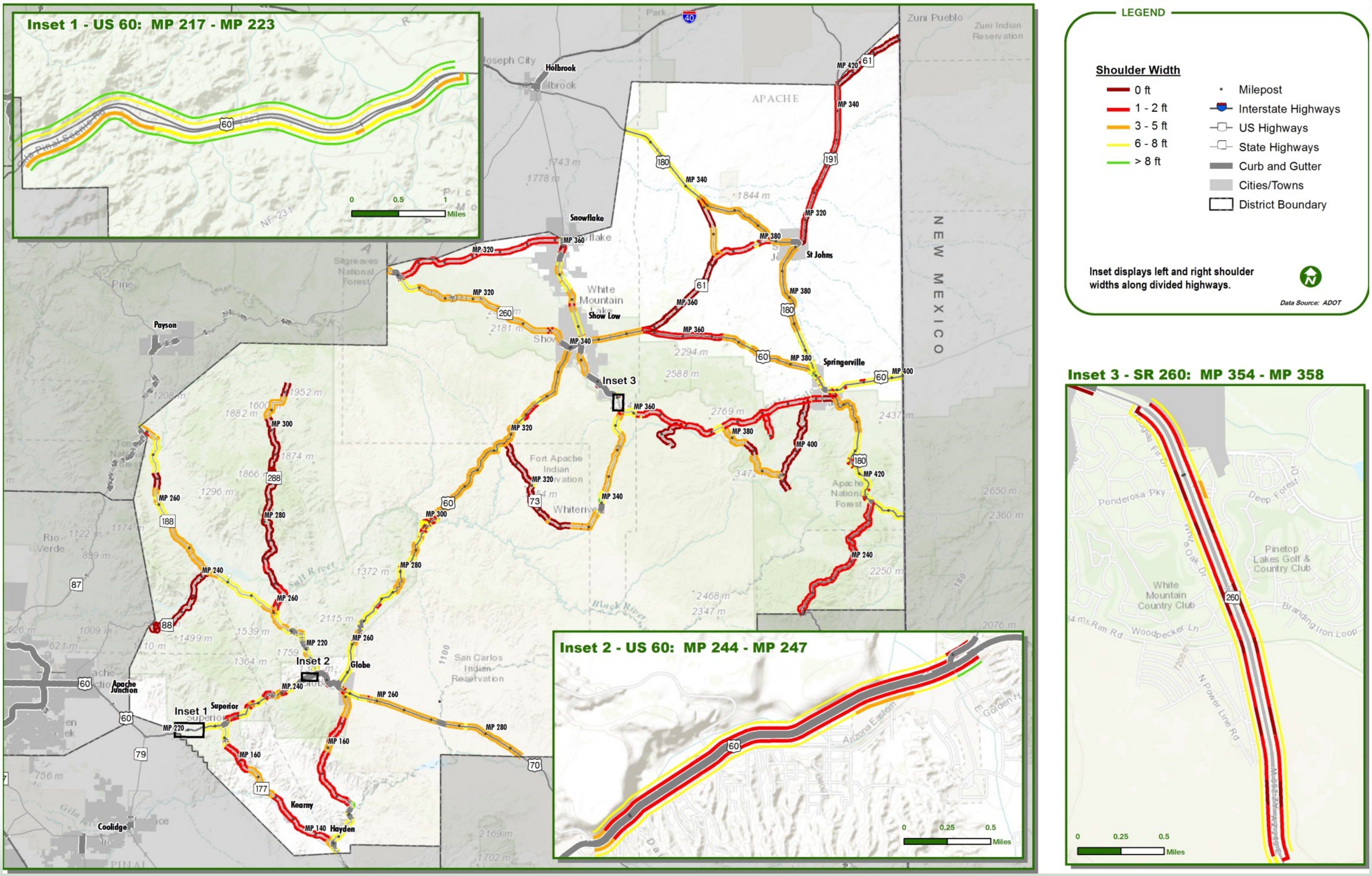


Figure 3.4: Existing Shoulder Conditions - Holbrook District

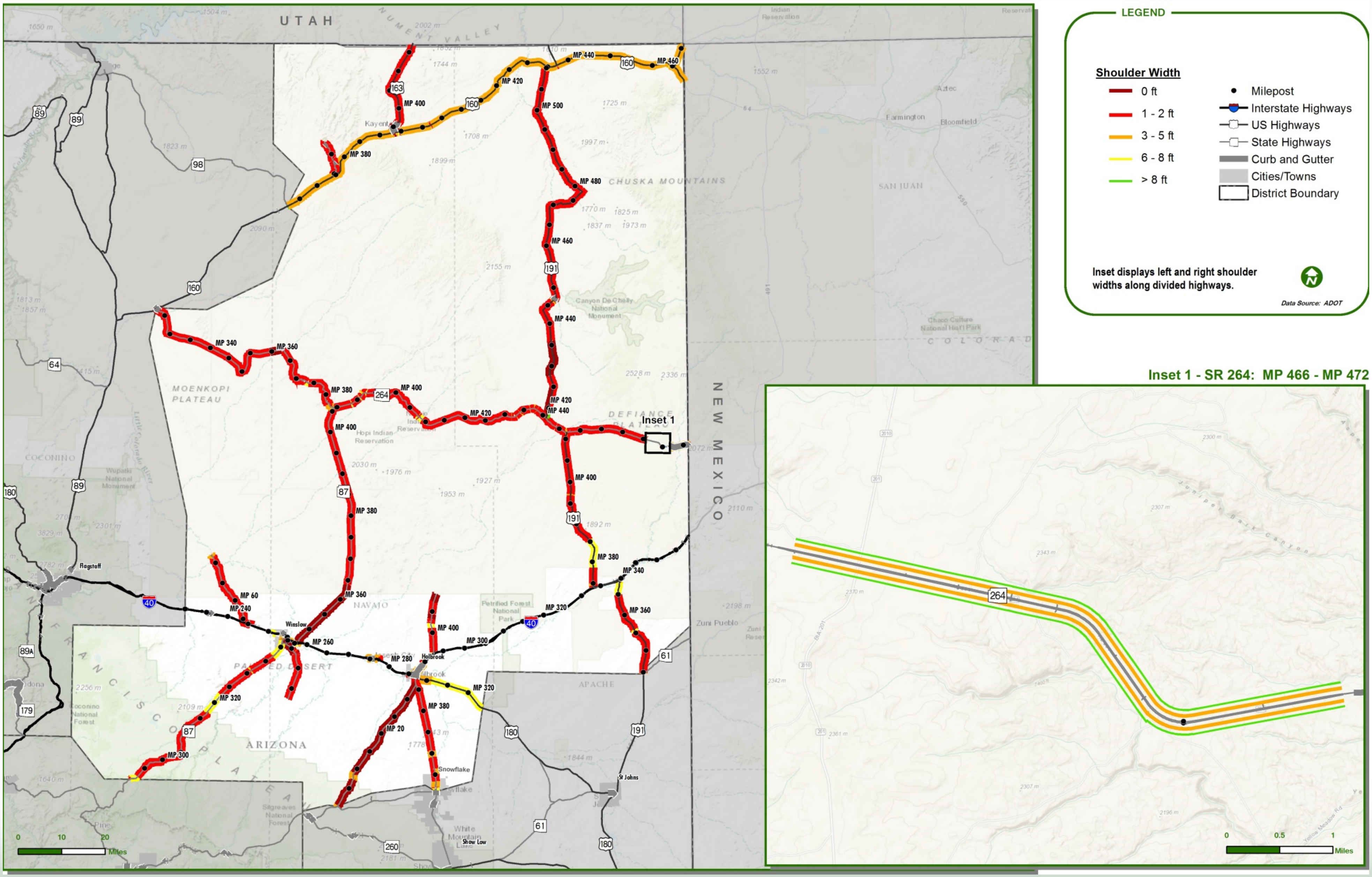


Figure 3.5: Existing Shoulder Conditions - Holbrook District (Divided Highways)

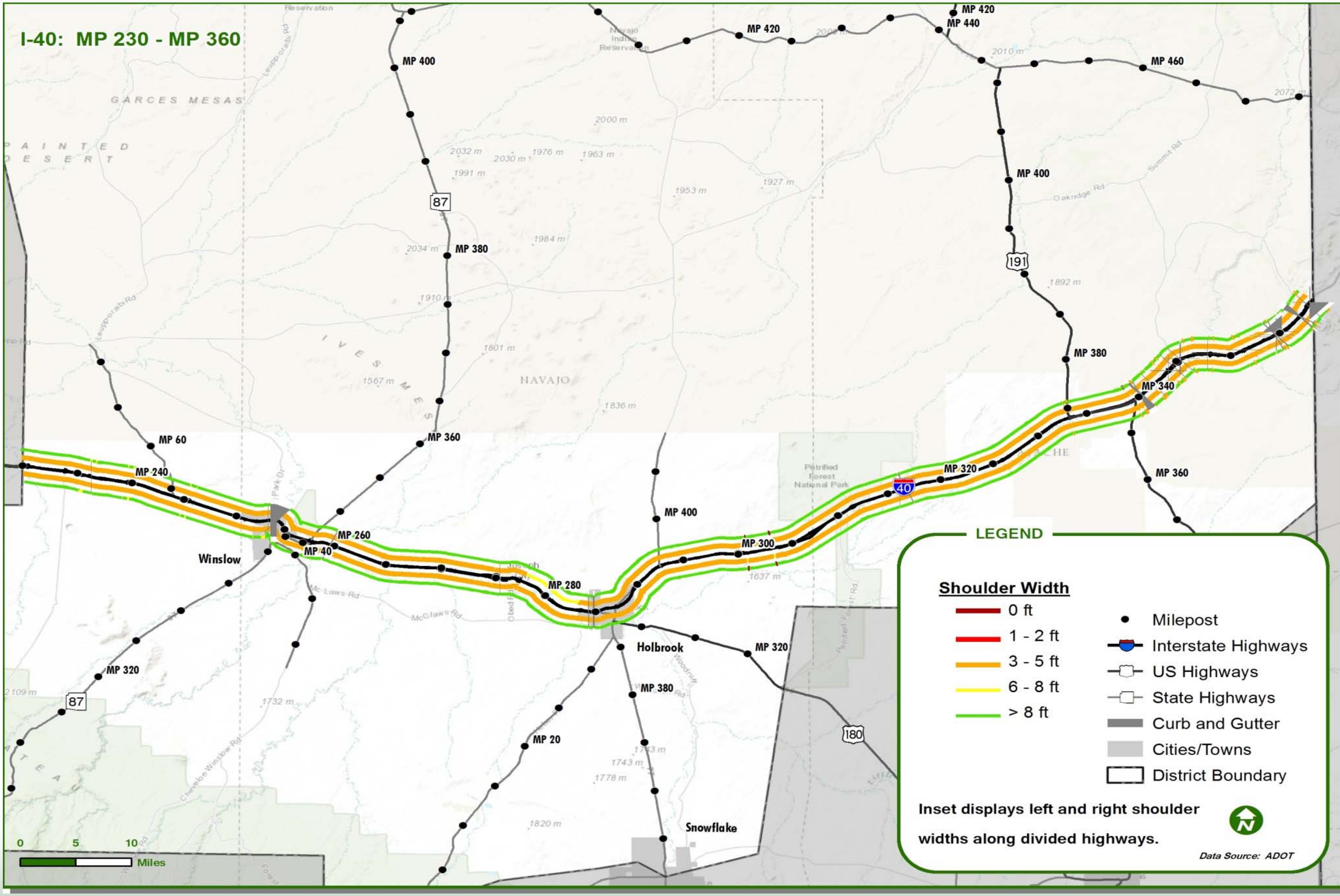


Figure 3.6: Existing Shoulder Conditions - Kingman District

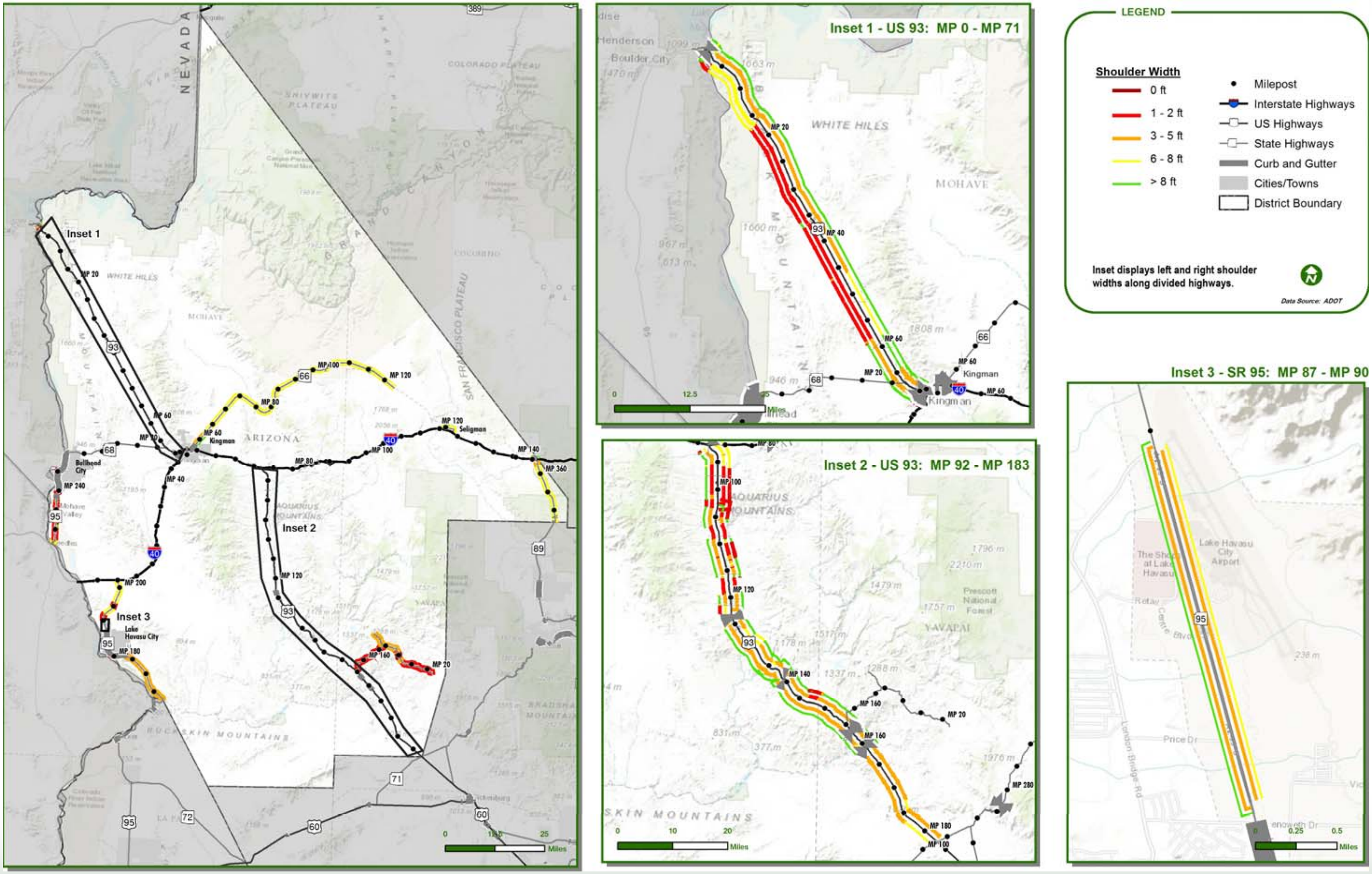


Figure 3.7: Existing Shoulder Conditions - Kingman District (Divided Highways)

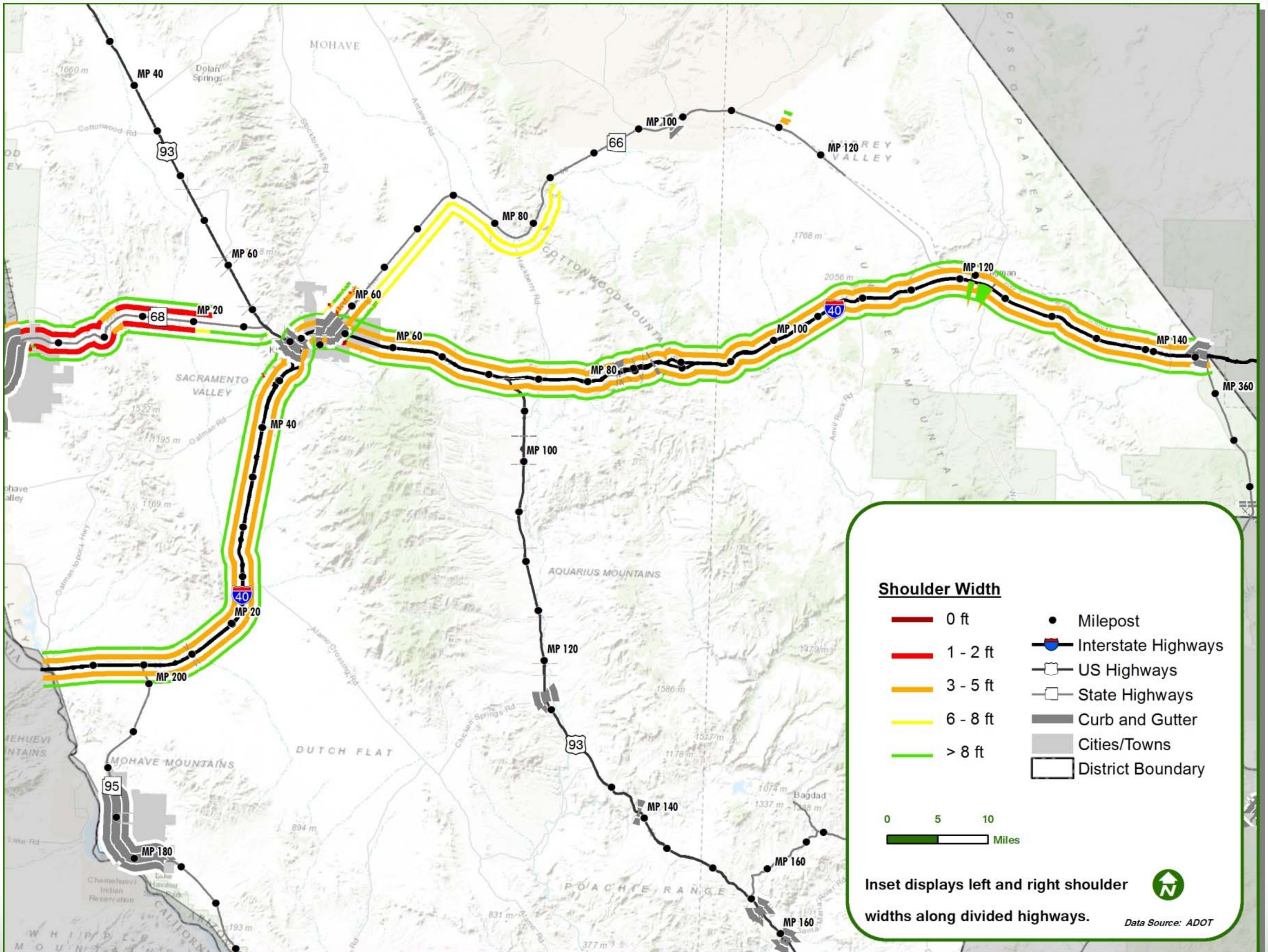


Figure 3.8: Existing Shoulder Conditions - Phoenix Maintenance District

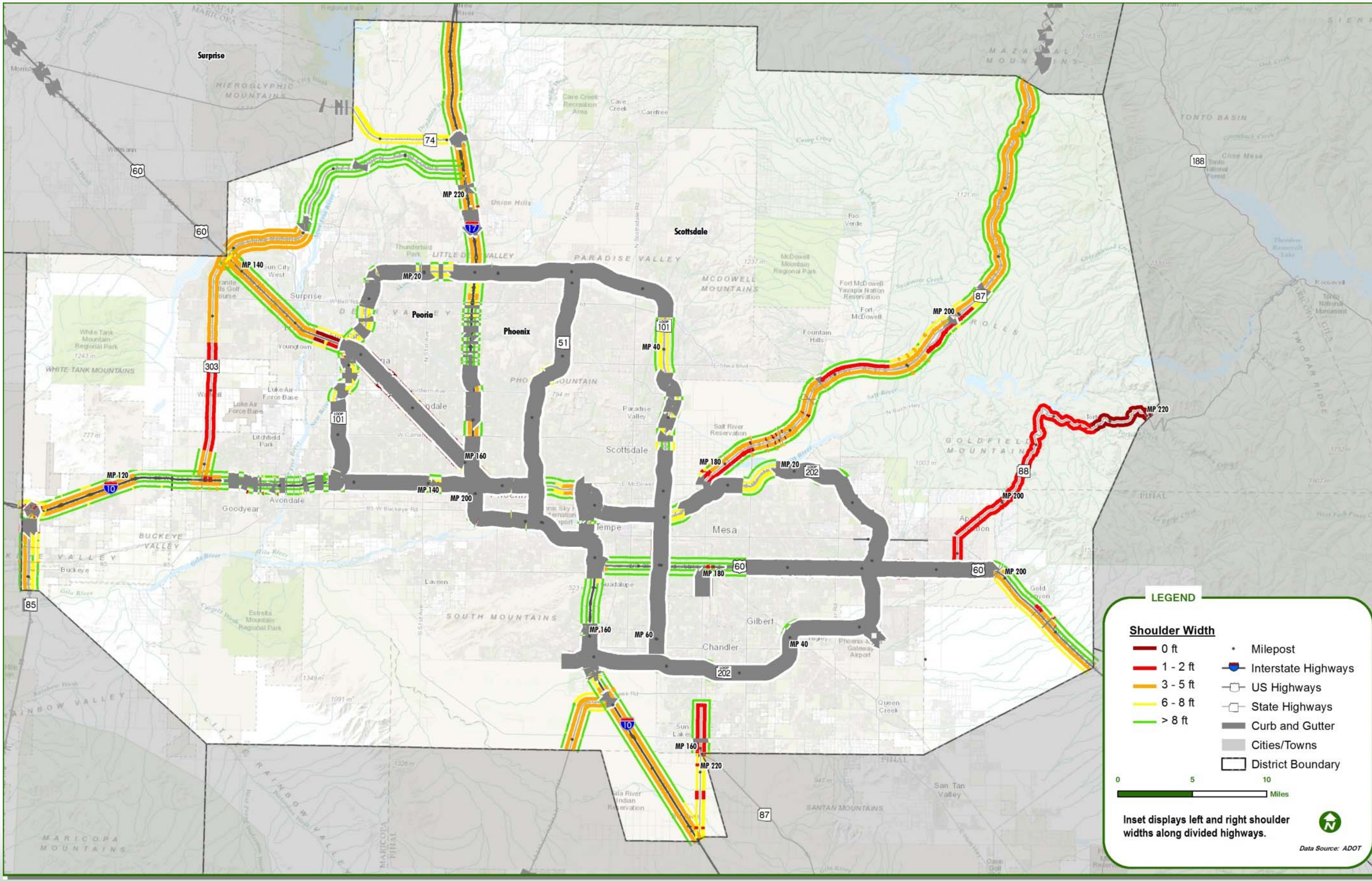


Figure 3.9: Existing Shoulder Conditions - Prescott District

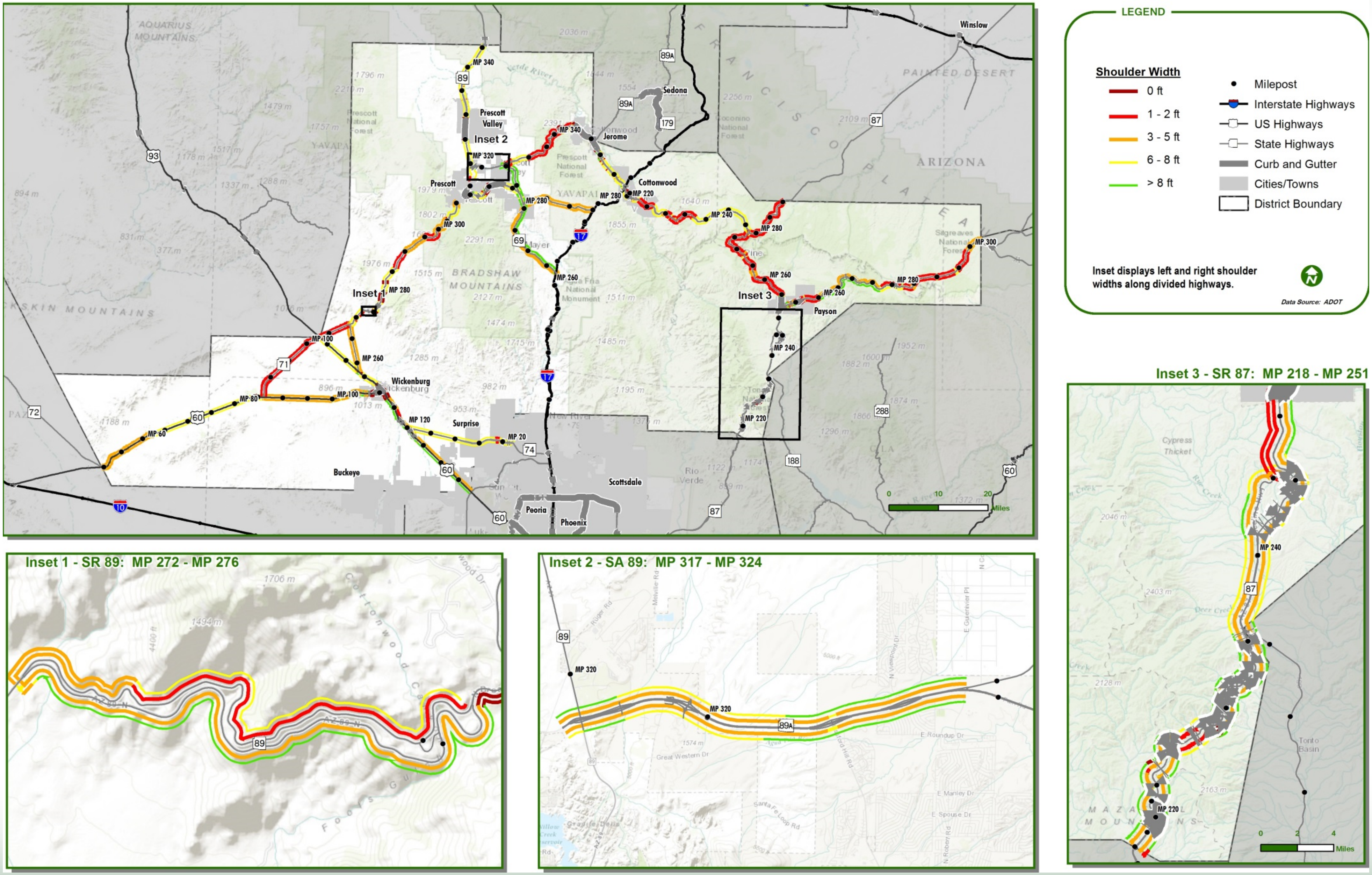


Figure 3.10: Existing Shoulder Conditions - Prescott District (Divided Highways)

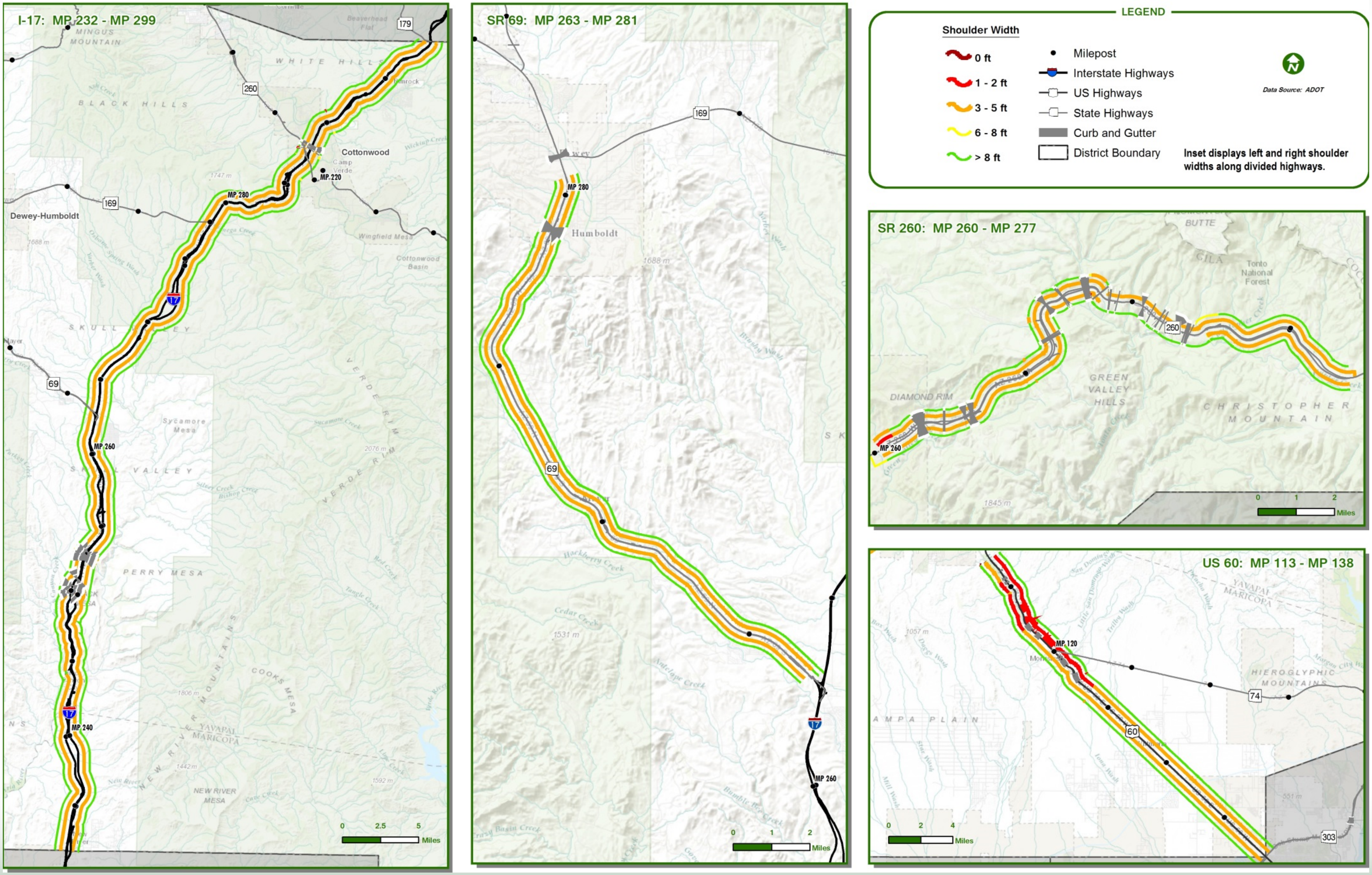


Figure 3.11: Existing Shoulder Conditions - Safford District

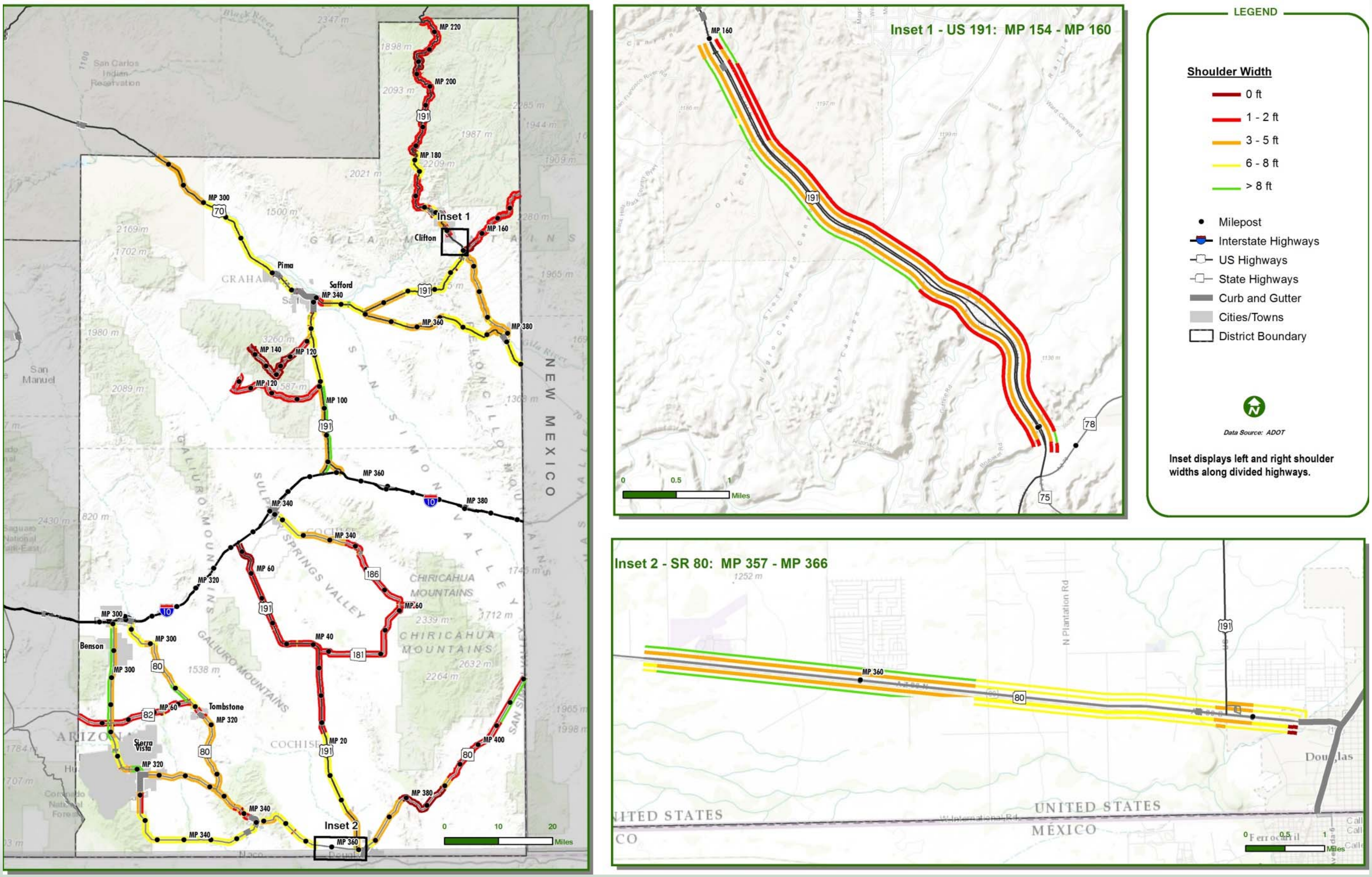


Figure 3.12: Existing Shoulder Conditions - Safford District (Divided Highways)

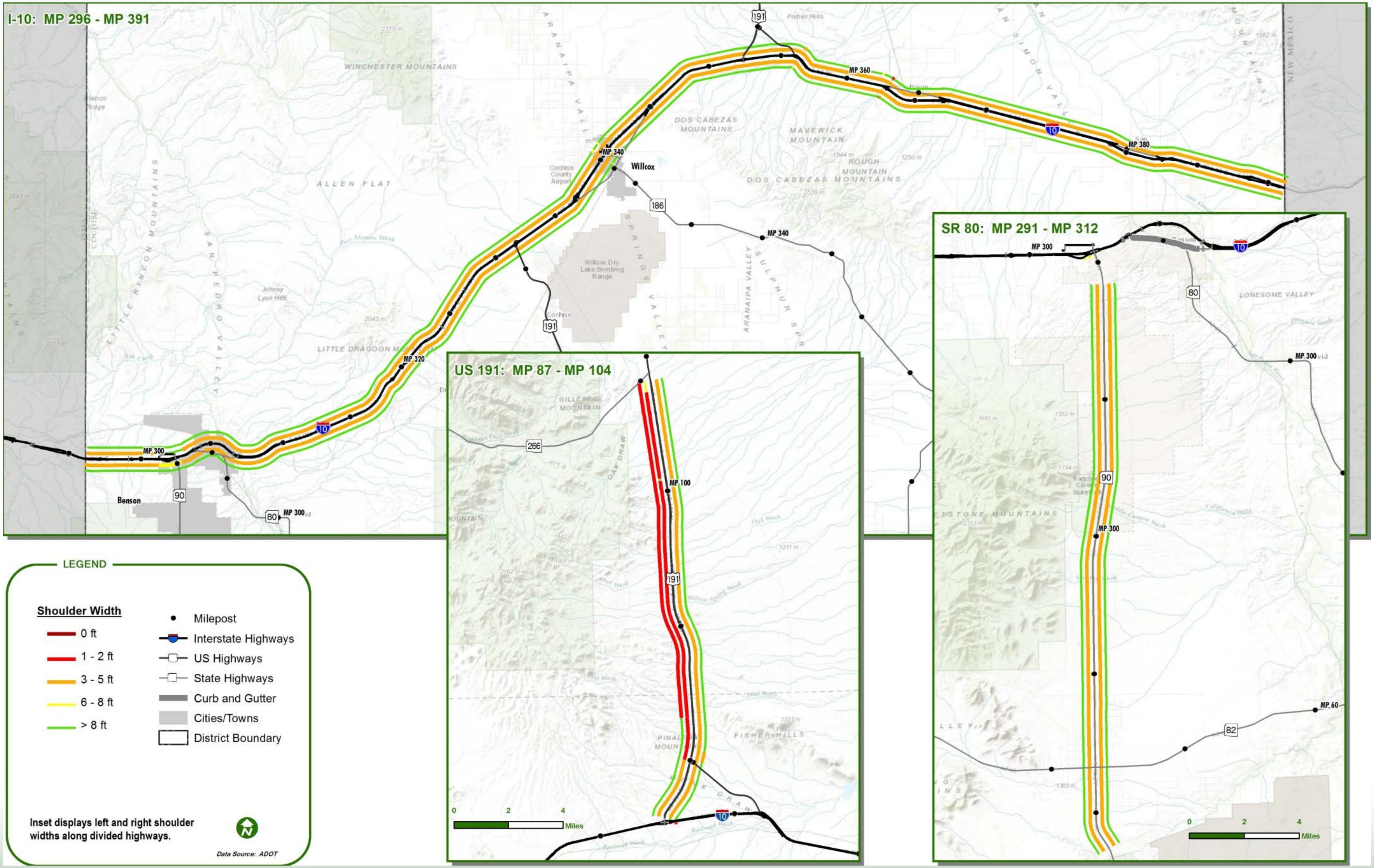


Figure 3.13: Existing Shoulder Conditions - Tucson District

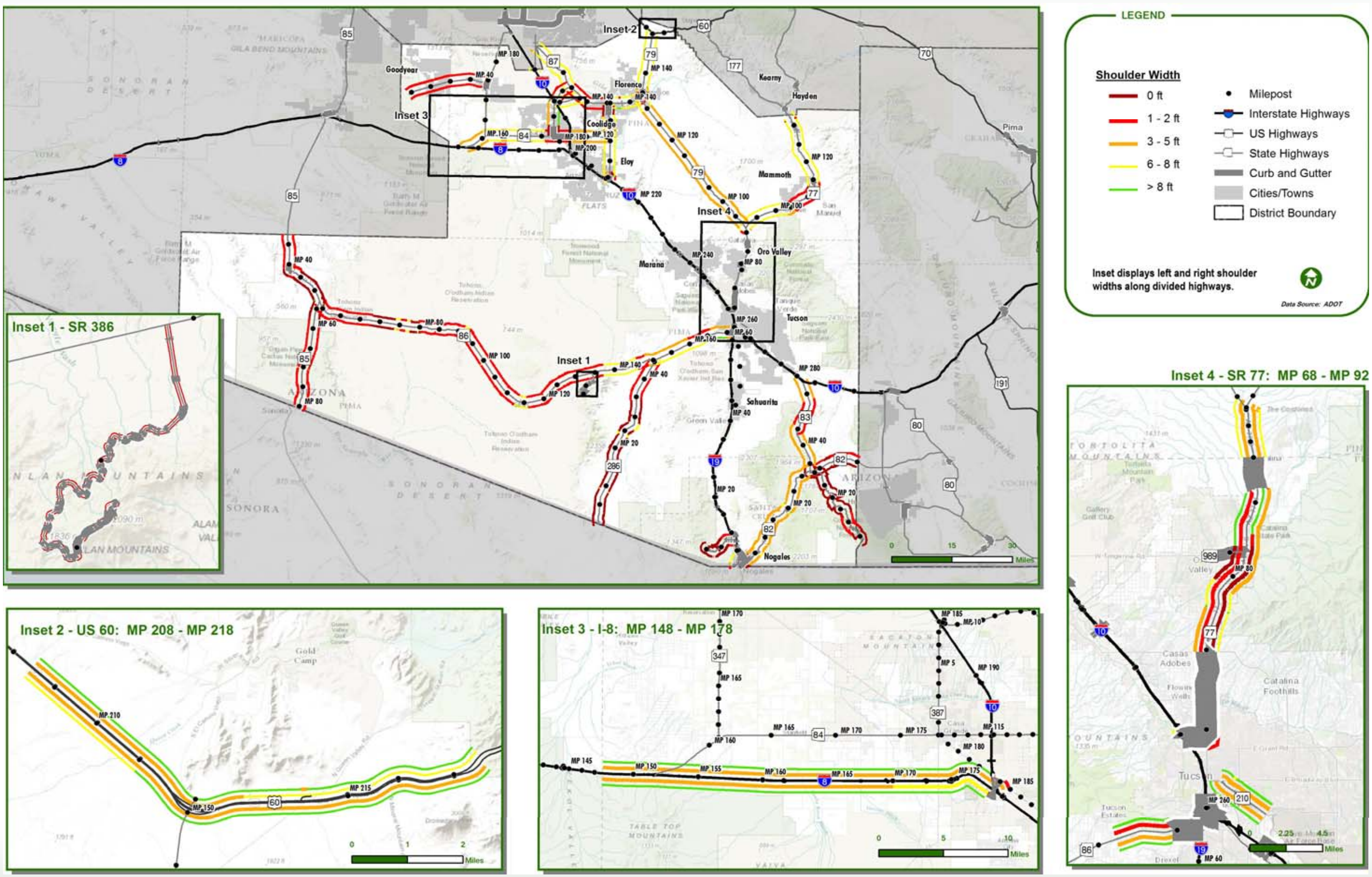


Figure 3.14: Existing Shoulder Conditions - Tucson District (Divided Highways)

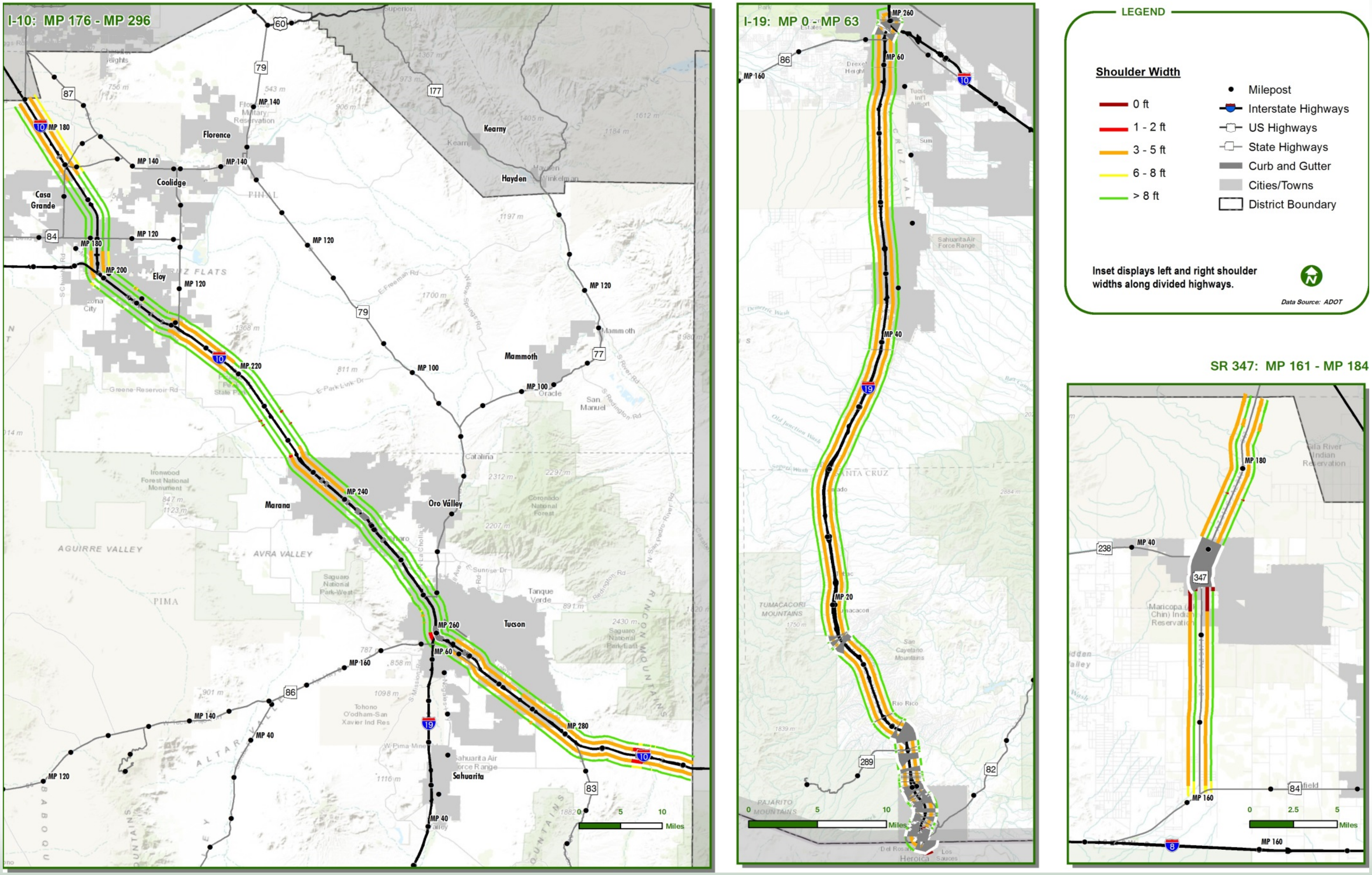


Figure 3.15: Existing Shoulder Conditions - Yuma District

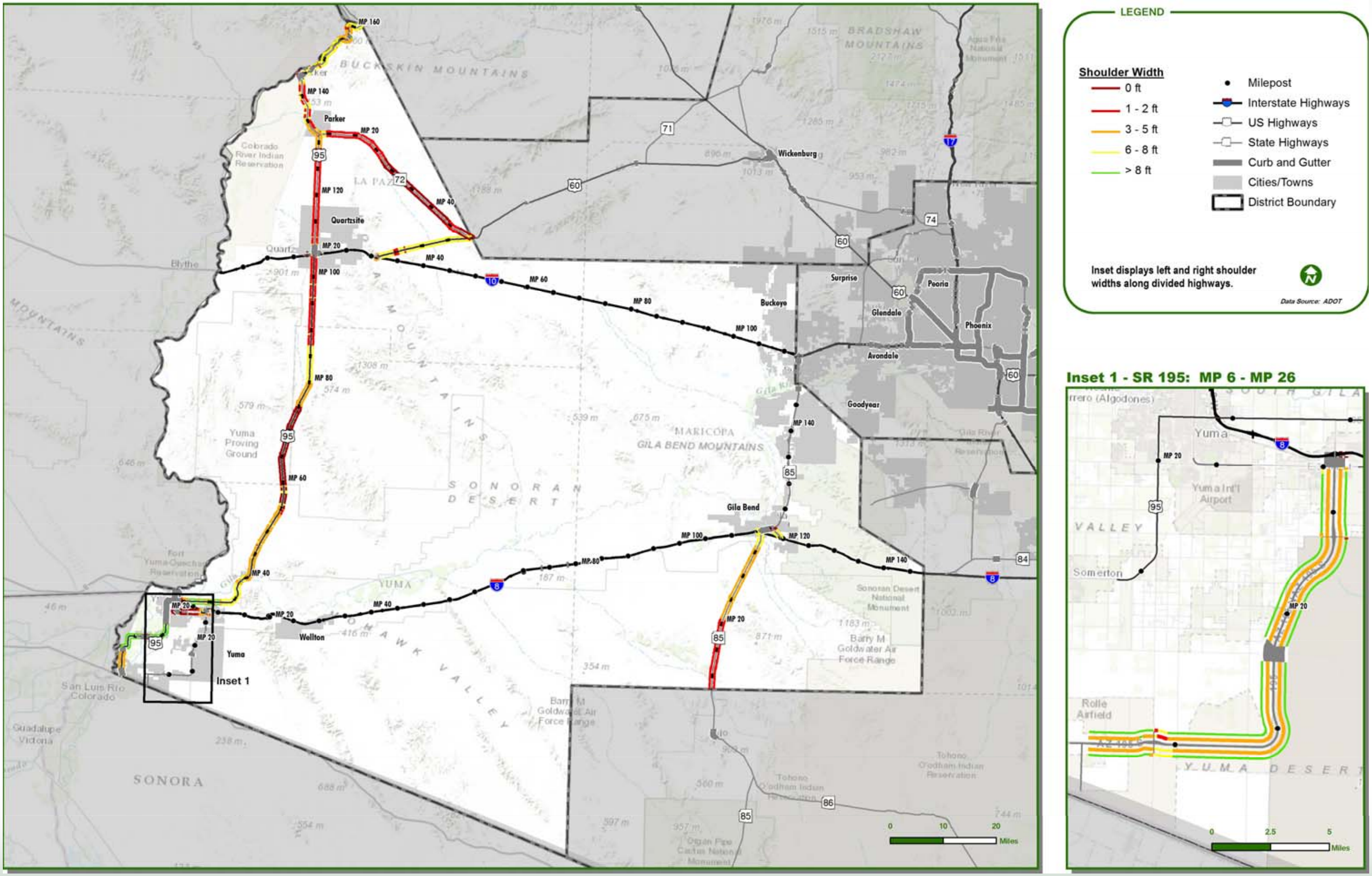
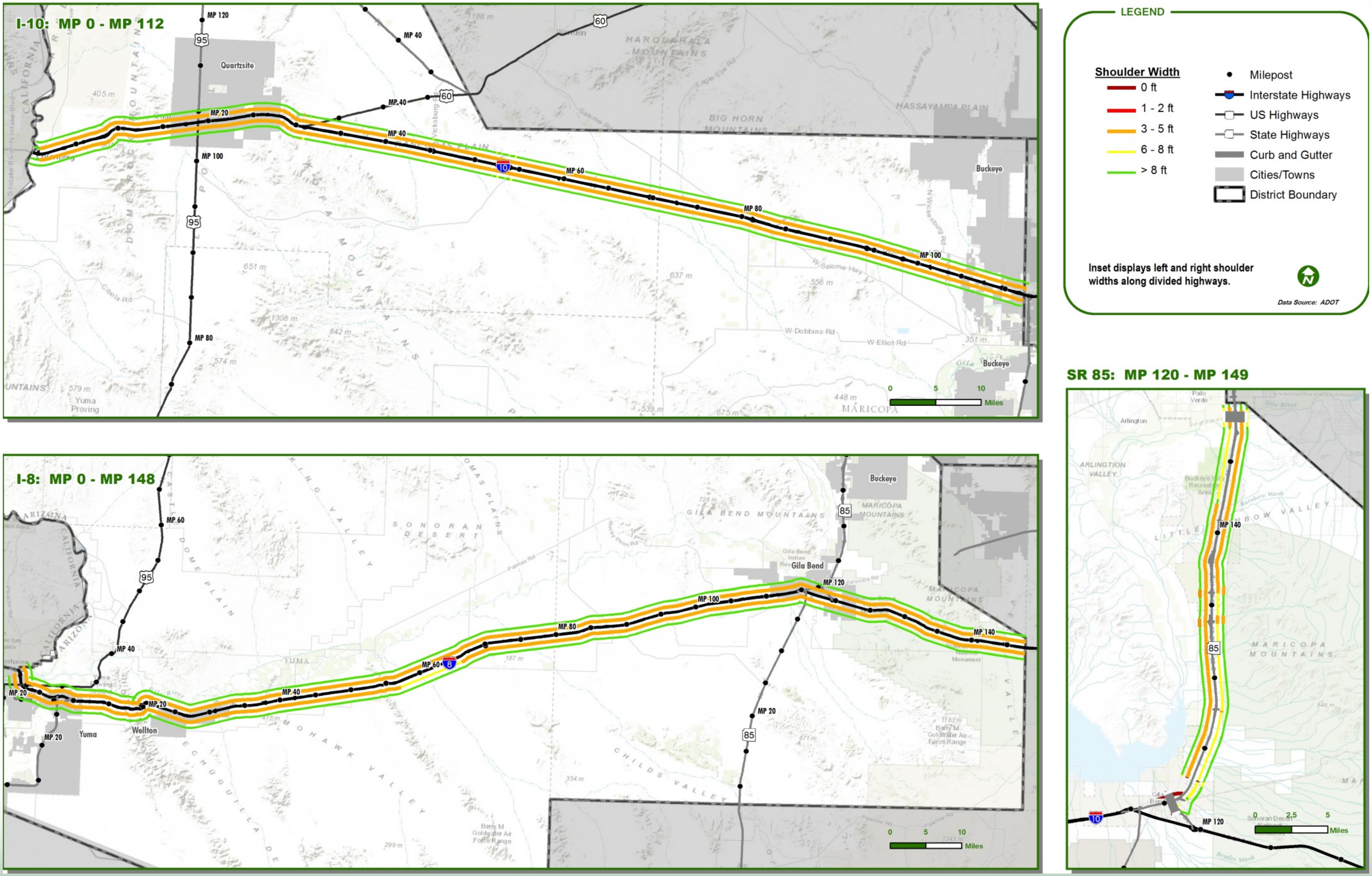


Figure 3.16: Existing Shoulder Conditions - Yuma District (Divided Highways)

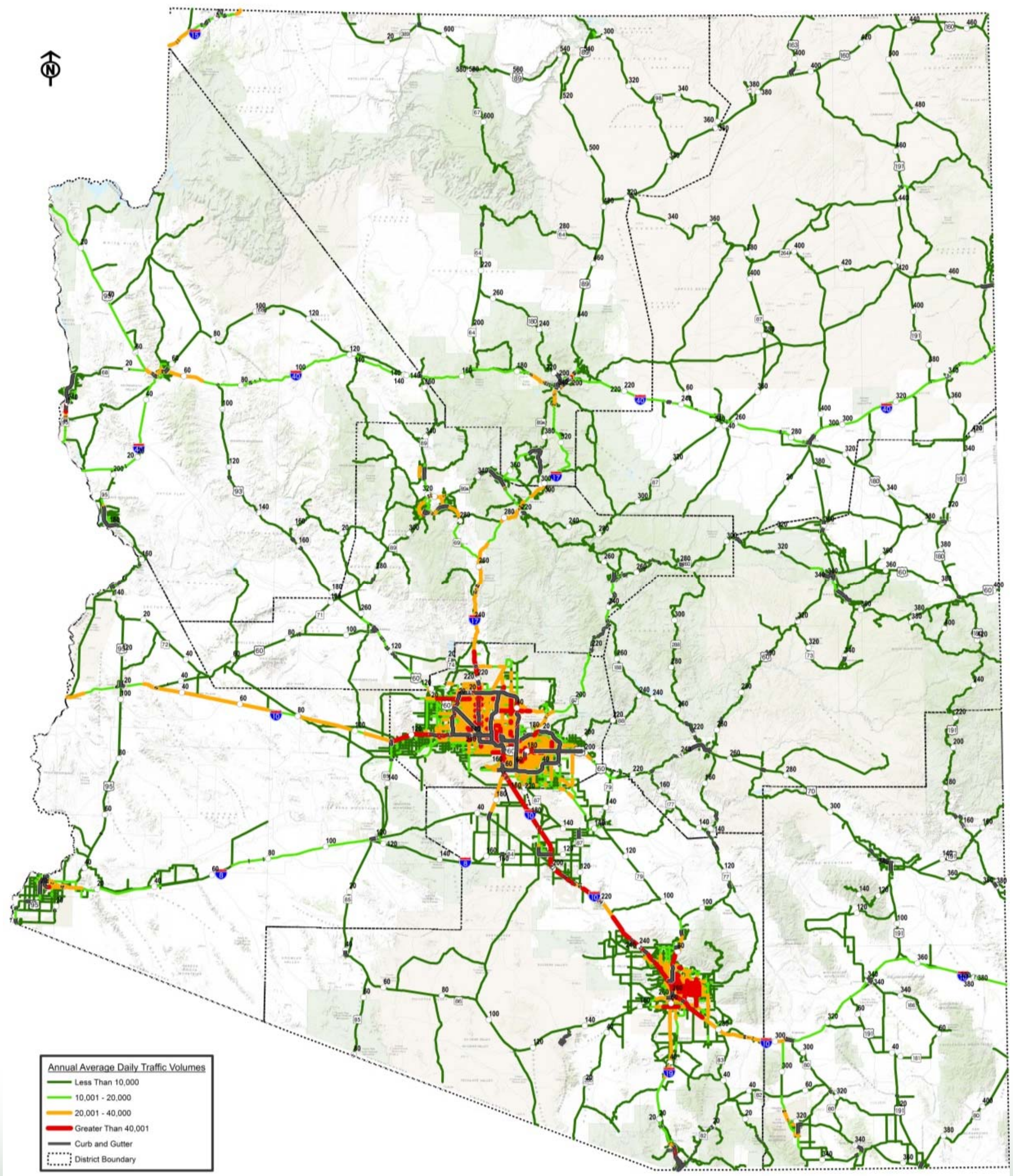


Existing Traffic Conditions

Existing traffic count data was obtained from ADOT to determine the existing traffic conditions on Arizona's State Highway System. Figure 3.17 illustrates the existing traffic conditions. Key traffic condition information illustrated in the figures includes:

- Highest traffic volumes are located within the Phoenix metropolitan area, along the I-10 corridor between Phoenix and Tucson, within the Tucson metropolitan area, and along interstates and highways entering urban areas.
- US 93, US 95, SR 89, SR 89A, SR 69, SR 87, US 60, and SR 90 have portions of the highway that have traffic volumes of over 10,000 AADT.

Figure 3.17: Existing Traffic Conditions

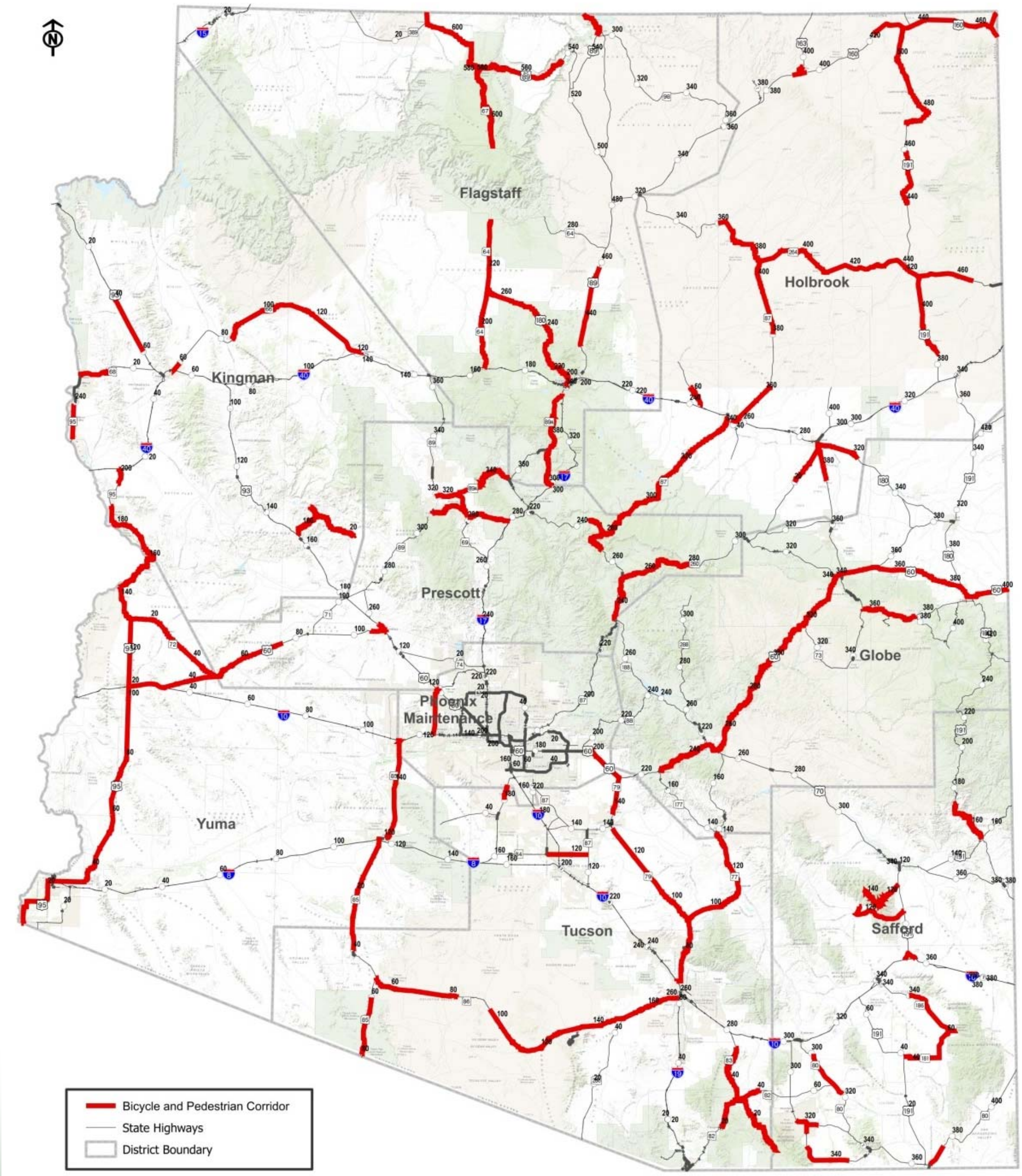


Pedestrian and Bicycle Routes

Sufficient shoulders are not only advantageous for motorists; shoulders provide bicyclist and pedestrians that utilize highways for recreational purposes or for general mobility, a safer alternative than riding within the travel lanes. In an effort to encourage bicycling and walking, the ADOT State Transportation Board initiated a policy of "promoting increased use of bicycling and walking, and accommodating bicycle and pedestrian needs in the planning, design, and construction of transportation facilities alongside state highways."

To assist in obtaining funding, shoulder conditions were analyzed against safety performance measures. Deficient road segments that are heavily utilized by pedestrians and/or bicyclists would receive a higher priority since the routes may not provide safe shoulder conditions. Figure 3.18 provides an illustration of the corridors that ADOT District Engineers deemed as high pedestrian/bicycle corridors.

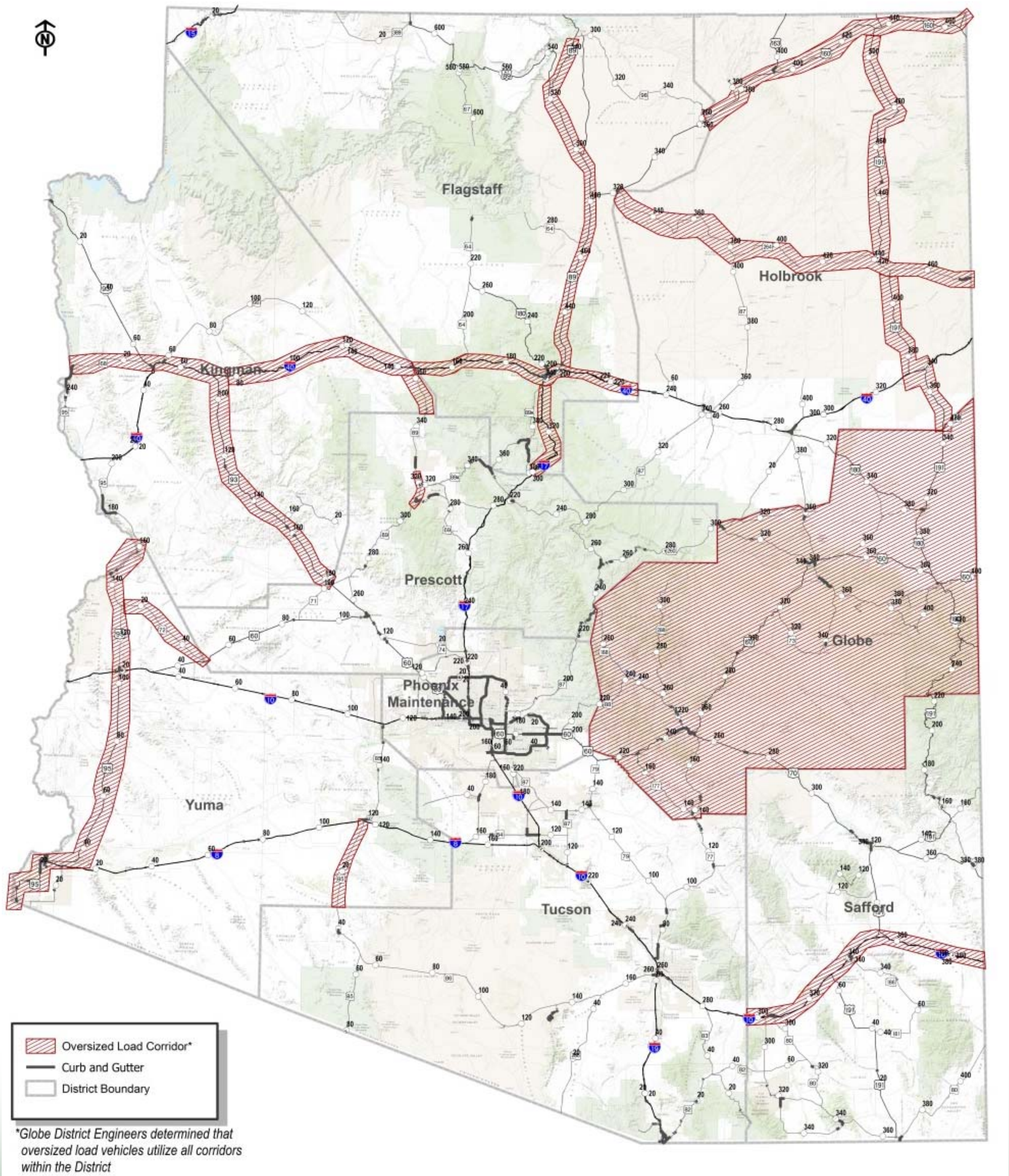
Figure 3.18: Pedestrian and Bicycle Corridors



Oversized Load Corridors

An oversized load is a vehicle that exceeds the standard legal size and/or weight limit for a roadway. Examples of oversize loads include construction machines, pre-built homes, shipping containers, etc. In Arizona, vehicles that exceed the legal dimensions are required to obtain a special permit to travel on state routes and may require an escort. Oversized loads often have a width greater than the standard travel lane width; therefore, on-coming traffic must utilize shoulders to allow the oversized loads to safely pass. In order to identify roadway segments that need to be improved to accommodate oversized vehicles, ADOT District Engineers were asked to identify oversized load corridors (See Figure 3.19).

Figure 3.19: Oversized Load Corridors



Crash Analysis

Crash analysis was conducted to identify trends, high crash rate corridors, and safety hazard locations that need to be addressed to improve safety. Data was obtained from ADOT's Accident Location Identification Surveillance System (ALISS) database for all crashes occurring between November 2008 and November 2013. The total number of crashes, crash rate, injury crash rate, and number of *equivalent property damage only crashes* (EPDO: Equivalent Property Damage Only) were estimated for each highway.

Crash rates are calculated to determine relative safety compared to other roadways, segments, or intersections. The combination of crash frequency (crashes per year) and vehicle exposure (traffic volumes or miles traveled) results in a crash rate. Crash rates are expressed in terms of crashes per million vehicle miles traveled for roadway segments. Figure 3.20 and Figure 3.21 illustrate crash rates along the Arizona State Highway System for 2-lane and multilane roadways, respectively.

Equivalent Property Damage Only

EPDO represents the relative number of Property Damage Only (PDO) or non-injury crashes. It takes into account the number of crashes and the severity of the crashes. Each crash is converted to an equivalent PDO using a multiplier for each crash type. Table 3.3 lists the multipliers used to derive the EPDO value. Figure 3.22 and Figure 3.23 illustrate the EPDO per lane along the Arizona State Highway System for 2-lane and multilane roadways, respectively.

Table 3.3: EPDO Conversion Factors

Crash Type	Equivalent PDO Crashes (multiplier)
Non-injury or Property Damage Only (PDO)	1
Possible Injury	2
Minor Injury	4
Severe Injury	7
Fatal	12

Figure 3.20: Crash Severity (Crash Rate) – Two-Lane Highways

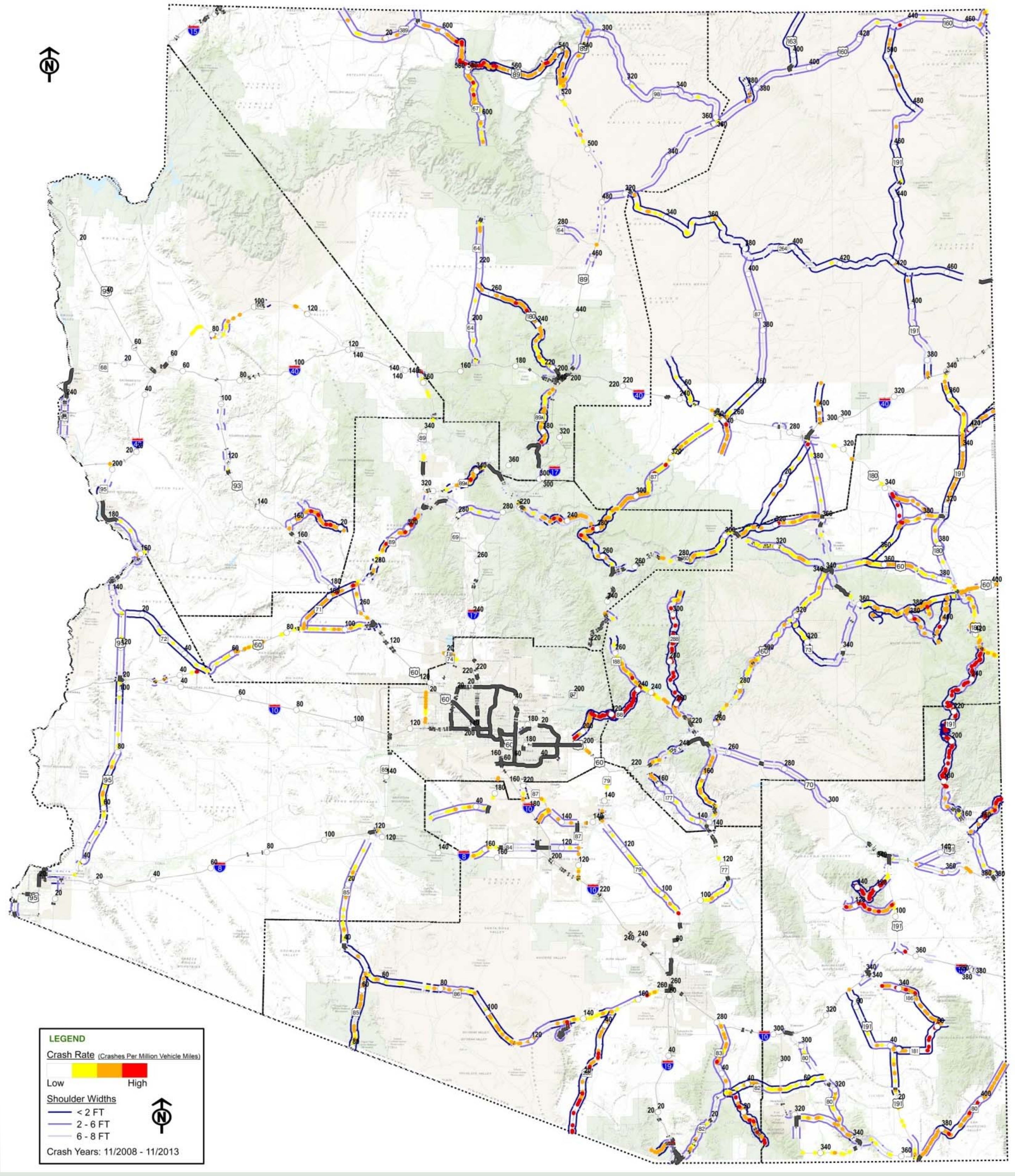


Figure 3.21: Crash Severity (Crash Rate) – Multilane Highways

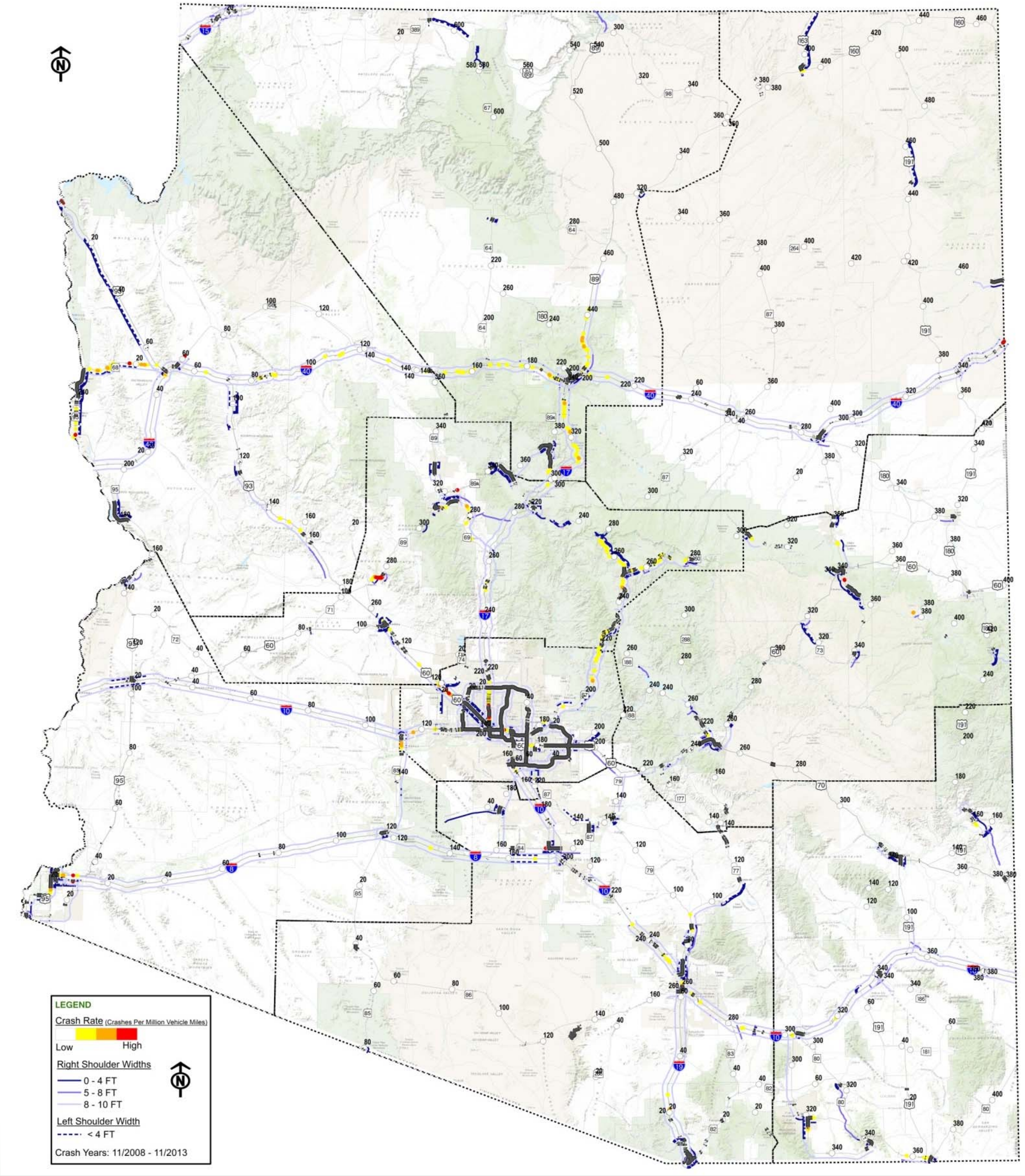


Figure 3.22: Crash Severity (EPDO) – Two-Lane Highways

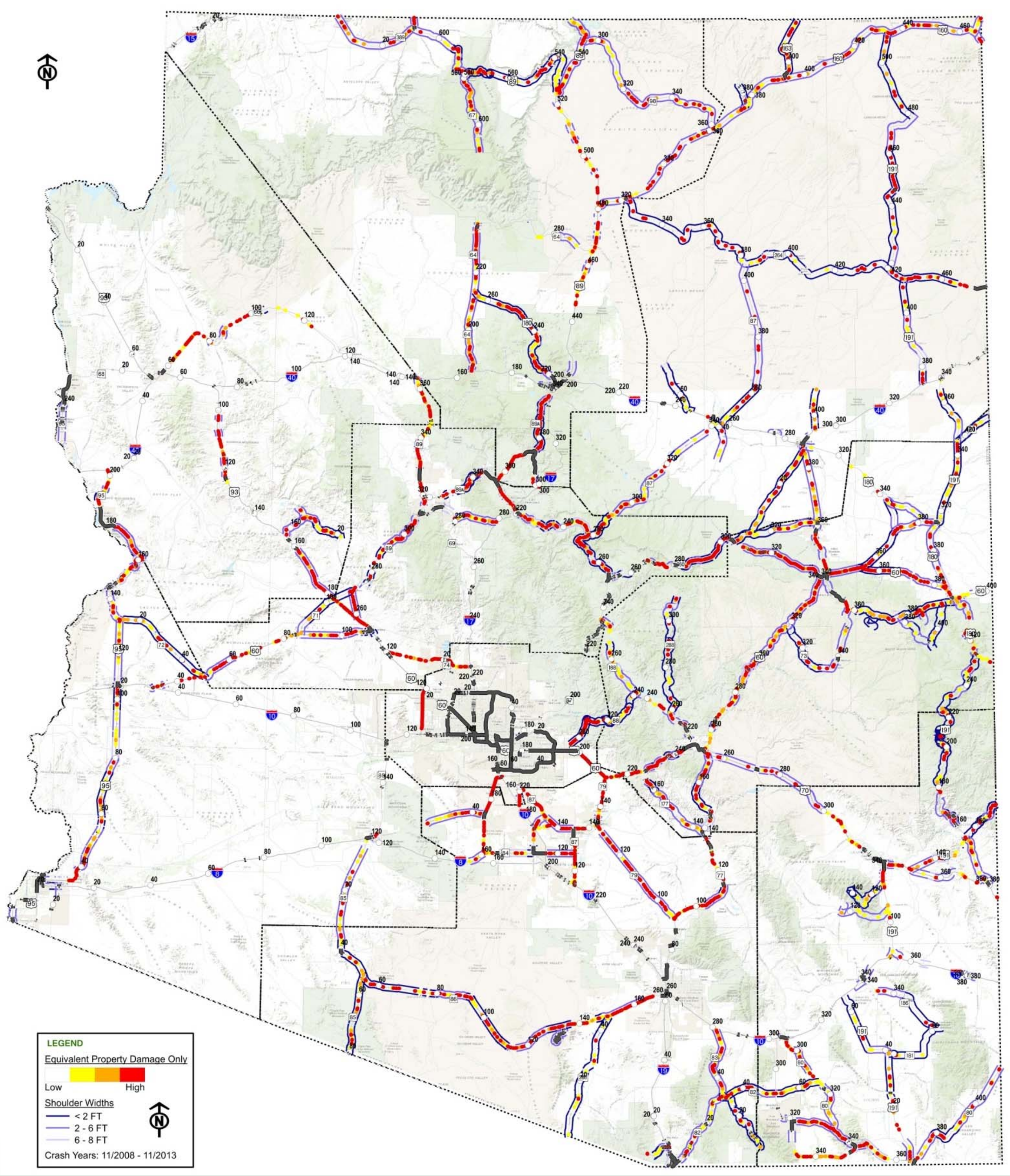
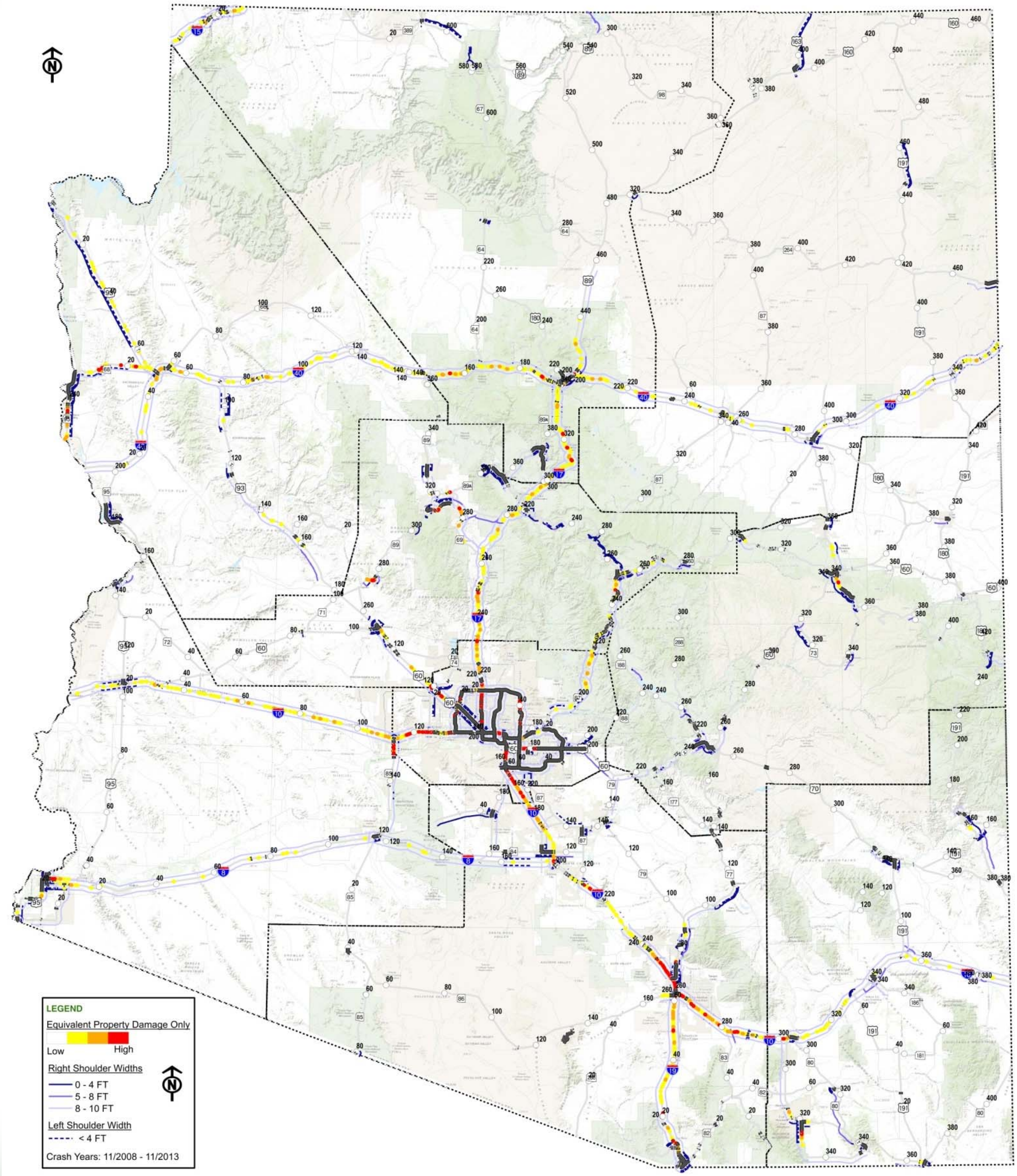


Figure 3.23: Crash Severity (EPDO) – Multilane Highways



Stakeholder Outreach - Phase I

Stakeholder Outreach - Phase I included individual meetings with each ADOT District staff. Meetings with the Districts were conducted April 22-April 30, 2014. The primary purpose of these meetings was to obtain feedback from each of the Districts about the following:

- Review and verify existing shoulder width conditions
- Review general and shoulder related crash data analysis results
- Identify any inconsistencies or errors in the background data
- Obtain Districts preference for preliminary project locations based on their understanding of local conditions
- Identify already planned and programmed improvements, if any
- Obtain consensus on evaluation criteria and preliminary prioritization methodology

Table 3.4 lists each District's suggested preliminary locations for shoulder improvements. The beginning and ending milepost ranges in the table represent the general problem area and not the exact location and length for shoulder improvements. A full summary of the feedback received from each District is included in *Working Paper 1: Existing Conditions*.

Table 3.4: ADOT District Engineer Recommended Shoulder Improvement Locations

Route	Direction	BMP	EMP	District	Priority*	Comments
SR 179	NB/SB	298.87	306.00	Flagstaff	4	SR 17: I-17 to Village of Oak Creek
SR 64	EB/WB	185.46	237.08	Flagstaff	5	Pockets from Williams to Tusayan
SR 89A	NB/SB	374.84	398.93	Flagstaff	2	Rim to Flagstaff (project in the works)
SR 98	EB/WB	297.46	361.56	Flagstaff	8	Sections of SR 98
US 160	EB/WB	311.46	361.56	Flagstaff	7	Sections of US 160
US 180	EB/WB	215.44	265.77	Flagstaff	3	Northwest of Flagstaff (project in the works)
US 89	SB	455.00	430.00	Flagstaff	1	Wauneta to Sunset Crater
US 89A	NB/SB	533.00	543.00	Flagstaff	6	Areas of US 89A near Marble Canyon
SR 188	EB/WB	269.00	264.00	Globe	Low priority	
SR 288	EB/WB	305.00	311.90	Globe	Low priority	
SR 61	NB/SB	352.88	381.86	Globe	Low priority	
US 60	EB/WB	242.00	227.00	Globe	N/A	
US 60	EB/WB	282.00	300.00	Globe	N/A	
US 60	EB/WB	346.00	353.00	Globe	N/A	
US 60	EB/WB	358.00	369.00	Globe	N/A	
SR 264	EB/WB	384.00	321.97	Holbrook	N/A	SR 264 west of SR87
SR 377	NB/SB	0.00	33.83	Holbrook	N/A	
US 191	NB/SB	448.00	510.34	Holbrook	N/A	US 191 north of Chinle
US 93	Both	144.00	151.00	Kingman	1	

**Priority rankings were provided by each District. Priorities listed as "N/A" were not given a priority by the District.*

Table 3.4: ADOT District Engineer Recommended Shoulder Improvement Locations (Continued)

Route	Direction	BMP	EMP	District	Priority*	Comments
SR 260	EB/WB	282.50	302.70	Prescott	N/A	H8245
SR 71	NB/SB	85.80	108.40	Prescott	N/A	
SR 71	NB/SB	108.80	109.60	Prescott	7	
SR 87	SB	246.20	250.90	Prescott	1	
SR 87	NB/SB	255.90	266.00	Prescott	2	
SR 87	NB/SB	268.20	270.50	Prescott	N/A	To be considered for climbing / passing lanes
SR 87	NB/SB	270.50	278.30	Prescott	6	
SR 87	NB/SB	278.70	290.10	Prescott	N/A	
SR 89	NB/SB	258.40	267.80	Prescott	3	
SR 89	NB/SB	278.20	282.70	Prescott	8	(280.4 - 281.9 exception)
SR 89	NB/SB	286.20	307.60	Prescott	N/A	
SR 89	NB/SB	307.60	309.50	Prescott	4	
SR 89A	NB/SB	324.80	326.10	Prescott	5	
SR 89A	NB/SB	329.80	331.20	Prescott	N/A	H8377
SR 89A	NB/SB	331.60	333.00	Prescott	10	
SR 89A	NB/SB	346.10	349.00	Prescott	9	
SR 72	EB/WB	13.11	49.91	Yuma	1	
SR 85	NB/SB	0.00	32.50	Yuma	3	SR 85 South
SR 95	NB/SB	132.00	143.93	Yuma	2	SR 72 Jct.-Parker
US 95	NB/SB	47.00	104.51	Yuma	4	Aberdeen Road-Quartzsite

**Priority rankings were provided by each District. Priorities listed as "N/A" were not given a priority by the District.*

4. Identification and Prioritization Methodology

Two-lane highways and multilane highways have different physical and traffic characteristics and their mobility and safety performance is evaluated using different parameters. For this reason, separate methodologies were developed to identify and prioritize:

- Shoulder improvements on two-lane highways
- Shoulder improvements on multilane highways

Methodology to Identify Shoulder Improvements on Two-Lane Highways

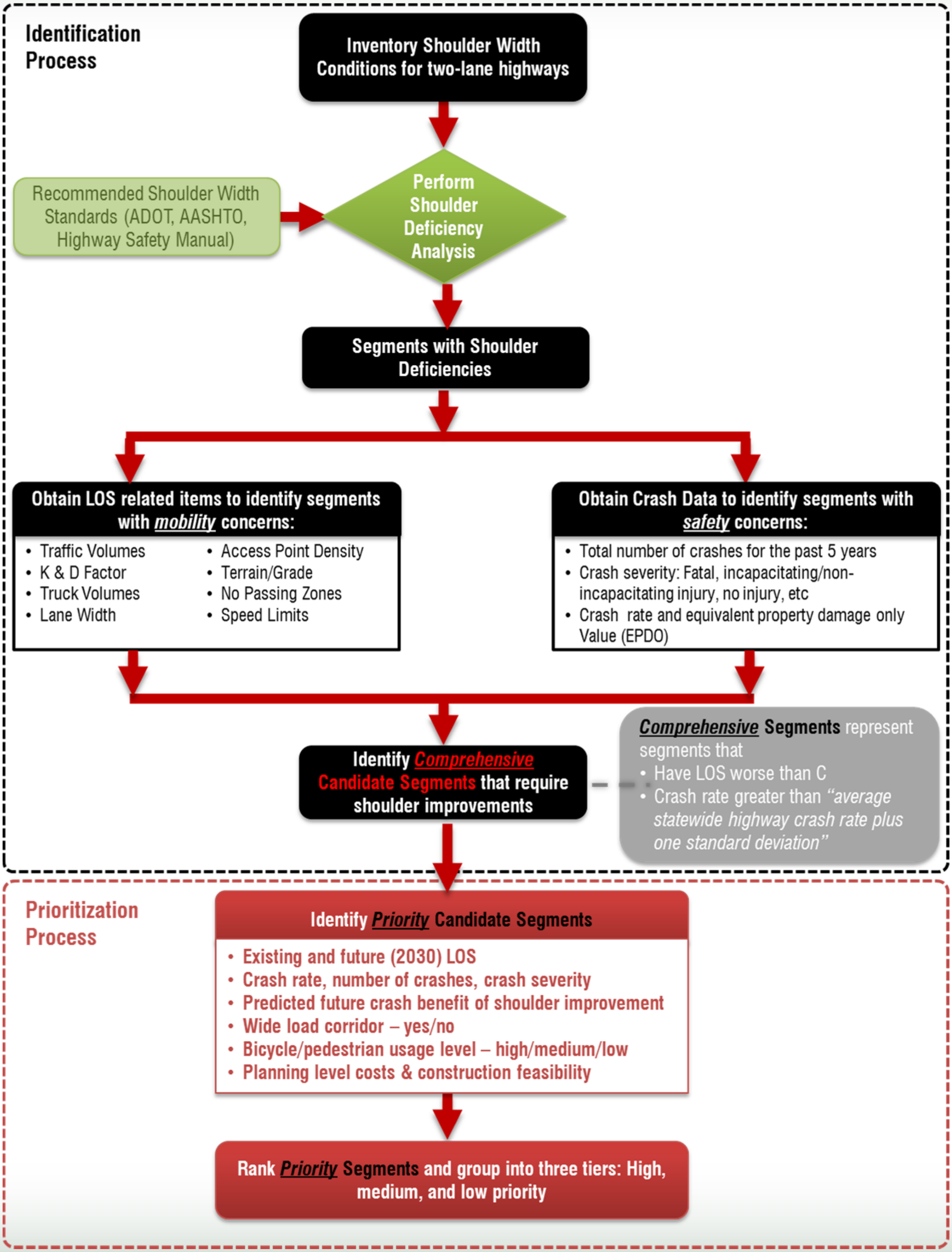
Figure 4.1 illustrates the steps utilized to identify and prioritize potential locations for shoulder improvements on two-lane highways. Once preliminary lists of potential candidates were identified, they were ranked on a statewide basis using the criteria and score ranges listed in Table 4.1.

Table 4.1: Prioritization Criteria for Shoulder Improvements on Two-Lane Highways

Criteria	Max Points	Points Distribution
Mobility – 25%	**25**	
Existing LOS: PTSF – Percent Time Spent Following	5	Z-score method*
Existing LOS: PFFS – Percent of Free Flow Speed	5	Z-score method*
Future LOS: PTSF – Percent Time Spent Following	5	Z-score method*
Future LOS: PFFS – Percent of Free Flow Speed	5	Z-score method*
Wide Load Corridor	5	5 points if segment was a wide load corridor; 0 points if NOT a wide load corridor
Safety – 50%	**50**	
Existing Crash Rate	15	Z-score method*
Existing Crash Severity (EPDO)	15	Z-score method*
Future Crash Severity (Potential Future Crash Benefit)	10	Z-score method*
Bicycle/Pedestrian Usage Level	10	10 points for segments with high bike/ped usage; 0 points if NOT a bike/ped corridor
Construction Feasibility - 25%	**25**	
Cost Per Lane Mile	10	Proportional distribution of points based on cost per lane mile
Potential Number of Bridges that Require Widening	15	0 bridges = 15 pts; 1 bridge = 12 pts; 2 bridges = 10 pts; 3 bridges = 8 pts; 4 bridges = 6 pts; 5 bridges = 4 pts; 6 bridges = 2 pts; Greater than 6 bridges = 0 pts

**Each record's z-score was determined based on its relative distance from the mean of all records. Based on the record's z-score, a proportional point value between 0 and Max Points was then assigned to each record.*

Figure 4.1: Identification Process for Shoulder Improvements on Two-Lane Highways



Methodology to Identify Shoulder Improvements on Multilane Highways

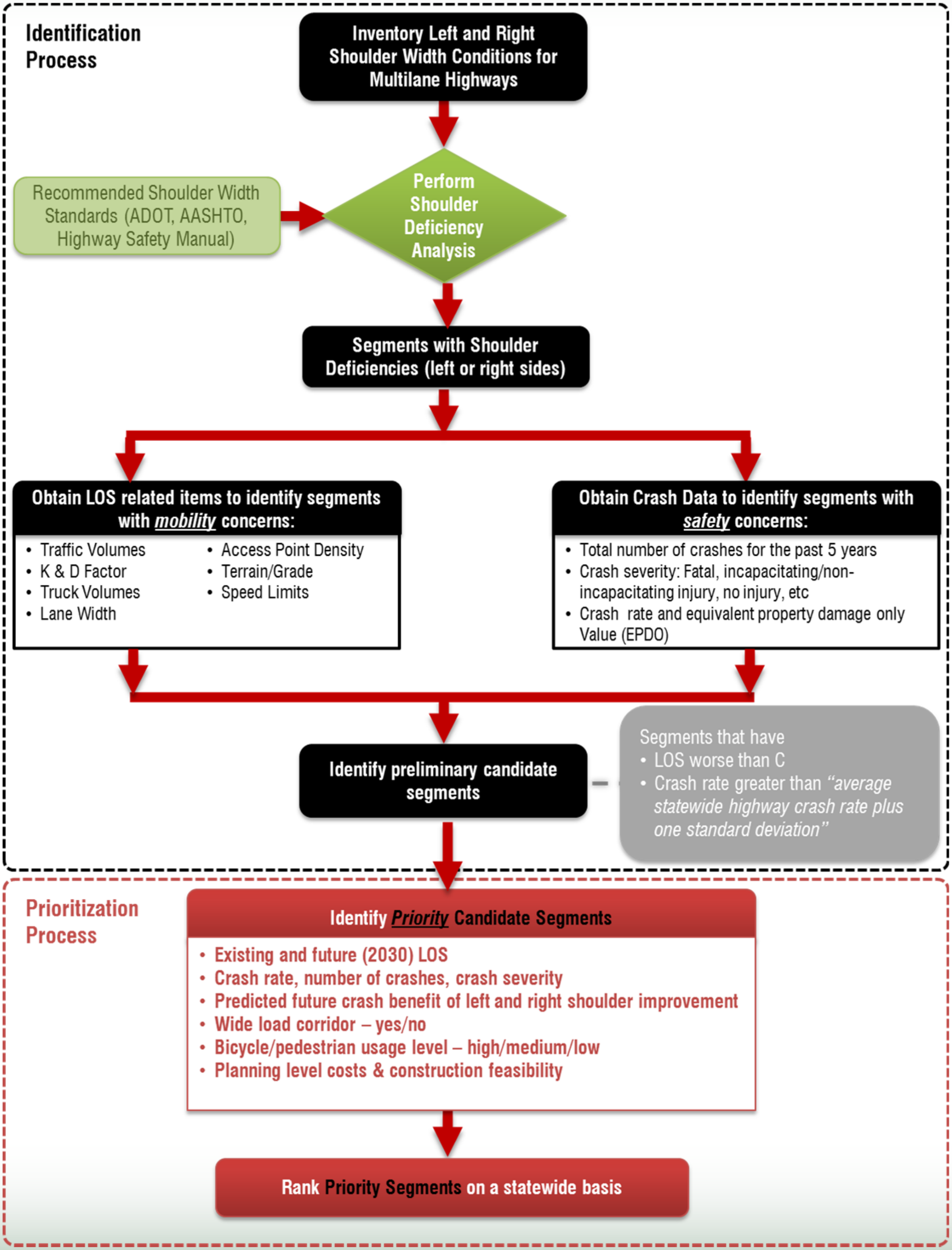
Figure 4.2 illustrates the steps utilized to identify and prioritize potential locations for shoulder improvements on multilane highways. Once preliminary lists of potential candidates were identified, they were ranked on a statewide basis using the criteria and score ranges listed in Table 4.2.

Table 4.2: Prioritization Criteria for Shoulder Improvements on Multilane Highways

Criteria	Max Points	Points Distribution
Mobility – 25%	**25**	
Existing LOS: Density	10	Z-score method*
Future LOS: Density	10	Z-score method*
Wide Load Corridor	5	5 points if segment was a wide load corridor; 0 points if NOT a wide load corridor
Safety – 50%	**50**	
Existing Crash Rate	15	Z-score method*
Existing Crash Severity (EPDO)	15	Z-score method*
Potential Future Crash Reduction Level – Right Shoulder	12	Z-score method*
Potential Future Crash Reduction Level – Left Shoulder	3	Z-score method*
Bicycle/Pedestrian Usage Level	5	10 points for segments with high bike/ped usage; 0 points if NOT a bike/ped corridor
Construction Feasibility 25%	**25**	
Cost Per Lane Mile	10	Proportional distribution of points based on cost per lane mile
Potential Number of Bridges that Require Widening	15	0 bridges = 15 pts; 1 bridge = 12 pts; 2 bridges = 10 pts; 3 bridges = 8 pts; 4 bridges = 6 pts; 5 bridges = 4 pts; 6 bridges = 2 pts; Greater than 6 bridges = 0 pts

***** *Each record's z-score was determined based on its relative distance from the mean of all records. Based on the record's z-score, a proportional point value between 0 and Max Points was then assigned to each record.*

Figure 4.2: Identification Process for Shoulder Improvements on Multilane Highways



Stakeholder Outreach – Phase II

The second phase of stakeholder outreach included individual meetings with each ADOT District staff. Meetings with the Districts were conducted October 8 – 15, 2014. The primary purpose of these meetings was to review:

- Design guidelines used to define deficiencies
- Listing of preliminary candidate locations
- District suggested locations
- Crash data analysis results
- Recommended ranking/prioritization criteria

The study team presented the design guidelines used to define shoulder deficiencies. 2014 ADOT Roadway Design Guidelines, the AASHTO Design Guidelines, and the Highway Safety Manual (HSM) criteria were evaluated. ADOT's Roadway Design Guidelines were used as the primary criteria to identify shoulder deficiencies.

HSM indicated that widening the shoulder from 6 – 8 ft may not yield a significant reduction in crashes; the study team recommended that roadway segments that had at least 6 ft of shoulder width be eliminated from consideration for two-lane highways. District staff concurred with the recommendation and asked the study team to confirm that shoulder related crashes were not a concern before eliminating those segments from consideration. District staff also concurred with the study team's suggestion to remove segments that have 8 – 10 ft shoulder on multilane highways unless crash analysis warrants the need for shoulder improvements.

A full summary of the feedback received from each District is included in *Working Paper 2: Evaluation Criteria and Plan for Improvements.*

5. Summary Results – Shoulder Improvements on Two-Lane Highways

For two-lane highways, a shoulder deficiency analysis was conducted to identify all highway segments that did not meet minimum shoulder width standards. These segments were then evaluated against the following criteria to identify ***comprehensive candidate locations*** for shoulder improvements.

- LOS C or worse
- Crash rate is greater than "average statewide highway crash rate plus one standard deviation"

A review of the ***comprehensive candidate locations*** revealed that several segments were too long and may not be feasible for implementation. To help the Districts further prioritize the segments, each larger segment was divided into smaller segments. These smaller segments were evaluated against the following additional set of criteria to generate a list of **priority candidate locations** that would be easier to implement.

- Existing and future (2030) LOS
- Crash rate, number of crashes, crash severity
- Predicted future crash benefit of shoulder improvement
- Wide load corridor – yes/no
- Bicycle/pedestrian usage level – high/medium/low
- Planning level costs & construction feasibility

Example:

Comprehensive **Candidate Location Vs** ***Priority*** **Candidate Location**

Example:

SR 64: MP 196 to MP 233 ----> ***Comprehensive*** Candidate Location

SR 64: MP 202 to MP 204
SR 64: MP 218 to MP 220
SR 64: MP 224 to MP 226
--> ***Priority*** Candidate Locations

The **priority candidate locations** were scored and ranked at both Statewide and District level and grouped into three tiers – high, medium, and low priority. The results for each District are summarized in the following sections:

- ***Comprehensive candidate locations*** that need shoulder improvements
- Priority segments for shoulder improvements.

Figures 5.1 to 5.9 illustrate the shoulder improvements locations in each District followed by project summary sheets for the Tier 1 locations.

Locations identified for shoulder improvements in Tables 5.1 – 5.18 represent only the general problem area and not the exact location and length of the shoulder improvements.

Planning Level Cost Estimates

Planning level cost estimates were developed based on typical per-mile/foot construction costs for widening and are expressed in 2015 dollars and have not been field verified. The following assumptions were used to derive the planning level cost estimates for the Tier 1 (priority) candidate segments:

- Widening shoulder to 8 FT: $900,000/mile for flat terrain
  - For each segment, the actual footage of additional shoulder width needed was estimated and the cost was then prorated. For example, if the candidate segment currently has a 2 FT shoulder, the prorated cost to widen the shoulder an additional 6 FT to meet the 8 FT standard was estimated.
  - Existing actual shoulder widths varied within each candidate segment; therefore, segments were divided into 0-2 FT, 3-5 FT, 5-8 FT, and 8 FT or greater shoulder widths. The midpoint of the candidate segments shoulder width range was utilized as the basis for calculating cost estimates. For example, an average shoulder width of 1 FT was utilized for candidate segments with a shoulder width range between 0-2 FT, 4 FT for segments with a 3-5 FT range, and so forth.
- Topographical constraints:
  - Segments with rolling terrain – an additional 10% was added to the base widening cost
  - Segments with mountainous terrain: an additional 20% was added to the base widening cost
- Bridge Widening: $200/SQFT
  - The number of bridges within each candidate segment was obtained from the National Bridge Inventory database. Each bridge's overall length, width, and deck width was also obtained.
  - For each bridge, the additional square footage needed to widen the bridge was determined.
  - The cost to widen each bridge was then estimated.
- Costs associated with acquiring right-of-way, widening culverts, and environmental mitigation are not included in estimates.
- Unless otherwise noted, recommended projects are not yet funded.

Due to topographical or other physical constraints adjustment factors may need to be applied to the cost estimates to account for increased construction costs. During project implementation the costs for each project may vary; therefore, during the design phase a detailed analysis should be performed to determine actual costs.

Flagstaff District

Table 5.1 presents the list of candidate locations for shoulder improvements on two-lane highways in the Flagstaff District. The candidate locations are ranked at the statewide and district level and grouped into three tiers – high, medium, and low priority. Table 5.2 summarizes the priority candidate improvement locations by tier. Figure 5.1 illustrates the prioritization of improvement projects within the District.

Table 5.1: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
S 064	Both	185.6	187.2	MP185.6 - MP187.2
S 064	Both	187.9	194.0	MP187.9 - MP190
				MP190 - MP192
				MP192 - MP194
S 064	Both	196.0	233.6	MP196 - MP198
				MP198 - MP200
				MP200 - MP202
				MP202 - MP204
				MP204 - MP206
				MP210 - MP212
				MP212 - MP214
				MP214 - MP216
				MP216 - MP218
				MP218 - MP220
				MP220 - MP222
				MP222 - MP224
				MP224 - MP226
				MP226 - MP228
				MP228 - MP230
				MP230 - MP232
S 064	Westbound	234.3	235.3	MP234.3 - MP235.3
S 064	Both	236.0	237.0	MP267 - MP268
S 064	Both	281.7	289.5	MP284 - MP286
S 067	Both	579.0	610.0	
S 098	Both	294.0	361.0	MP298 - MP300
				MP300 - MP302
				MP302 - MP304
				MP308 - MP310
				MP318 - MP320
				MP328 - MP330

Table 5.1: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District (Continued)

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
				MP330 - MP332
				MP342 - MP344
				MP344 - MP346
				MP348 - MP350
				MP350 - MP352
				MP352 - MP354
				MP354 - MP356
S 179	Both	299.0	304.5	MP299 - MP302
				MP302 - MP304.5
S 389	Both	0.0	32.1	
SA089	Both	374.0	389.8	MP374 - MP376
				MP380 - MP382
				MP384 - MP386
				MP386 - MP389.8
SA089	Both	390.4	398.7	
U 089	Both	456.6	461.8	MP461.8 - MP460.7
U 089	Both	469.6	470.8	MP469.6 - MP470.8
U 089	Both	471.6	472.3	MP471.6 - MP472.3
U 089	Both	474.5	475.4	MP474.5 - MP475.4
U 089	Both	477.4	478.3	MP477.4 - MP478.3
U 089	Both	493.1	494.1	MP493.1 - MP494.1
U 089	Both	505.7	507.1	MP505.7 - MP507.1
U 089	Both	509.2	512.2	MP509.2 - MP512.2
U 089	Both	519.9	521.2	MP519.9 - MP521.2
U 089	Both	524.4	556.8	MP548 - MP550
				MP550 - MP552
				MP552 - MP554
				MP554 - MP556.8
U 160	Both	311.0	324.0	MP311 - MP314
				MP314 - MP316
				MP316 - MP318
				MP318 - MP320
U 160	Eastbound	324.0	332.0	

Table 5.1: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District (Continued)

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
U 160	Both	332.0	356.0	MP336 - MP338
				MP340 - MP342
				MP342 - MP344
				MP344 - MP346
				MP346 - MP348
				MP350 - MP352
				MP352 - MP354
				MP354 - MP356
U 160	Eastbound	356.0	358.0	MP356 - MP358
U 160	Both	358.0	362.0	MP358 - MP360
				MP360 - MP362
U 180	Both	218.0	237.4	MP218 - MP220 MP220 - MP223.2 MP223.2 - MP226
U 180	Both	239.4	244.2	
U 180	Both	245.4	264.0	
U 180	Eastbound	264.0	265.6	
UA089	Both	524.0	537.3	
UA089	Both	538.5	546.0	
UA089	Southbound	546.0	548.0	
UA089	Both	548.0	609.0	MP590 - MP592
UA089	Both	610.2	612.3	

Priority segments represent segments that
- Have LOS worse than C
- Crash rate greater than "average statewide highway crash rate plus one standard deviation"
District Rankings are Provided in the Following Table

Table 5.2: Two-Lane Highways - Ranking of Priority Candidate Locations in Flagstaff District

Route	Direction	BMP	EMP	Total Points	Tier Level	District Rank	Statewide Rank	Cost Estimate*
S 064	Both	185.6	187.2	79.33	1	1	6	$1,458,000
SA089	Both	374.0	376.0	76.02	1	2	23	$3,780,000
S 064	Both	187.9	190.0	75.49	1	3	28	$1,881,000
S 064	Both	236.0	237.0	72.80	1	4	45	$990,000
S 064	Both	224.0	226.0	71.35	1	5	55	$1,800,000
S 064	Both	230.0	232.0	71.01	1	6	57	$1,980,000
U 089	Both	474.5	475.4	70.65	1	7	60	$819,000
S 064	Westbound	234.3	235.3	70.57	1	8	61	$459,000
S 064	Both	226.0	228.0	70.57	1	9	62	$1,980,000
S 064	Both	218.0	220.0	70.39	1	10	63	$1,800,000
S 064	Both	222.0	224.0	70.24	1	11	65	$1,800,000
U 089	Both	461.8	460.7	70.12	1	12	67	$981,000
S 064	Both	228.0	230.0	69.96	1	13	68	$1,980,000
S 064	Both	190.0	192.0	69.75	1	14	72	$1,980,000
S 064	Both	216.0	218.0	69.65	1	15	75	$1,800,000
S 064	Both	220.0	222.0	69.58	1	16	77	$1,800,000
S 064	Both	198.0	200.0	69.49	1	17	82	$1,980,000
S 064	Both	212.0	214.0	69.24	1	19	89	$1,800,000
U 089	Both	469.6	470.8	69.21	1	20	90	$1,044,000
S 064	Both	200.0	202.0	69.12	1	21	94	$1,980,000
S 064	Both	196.0	198.0	69.10	1	22	96	$1,980,000
S 064	Both	202.0	204.0	68.95	1	23	101	$1,980,000
S 064	Both	192.0	194.0	68.95	1	24	102	$1,980,000
U 089	Both	471.6	472.3	68.79	1	25	106	$657,000
S 064	Both	210.0	212.0	68.20	2	26	117	
S 064	Both	204.0	206.0	67.68	2	27	121	
S 064	Both	214.0	216.0	67.57	2	28	124	
SA089	Both	380.0	382.0	67.30	2	29	126	
SA089	Both	384.0	386.0	67.24	2	30	127	
SA089	Both	386.0	389.8	65.85	2	31	138	
U 089	Both	548.0	550.0	65.82	2	32	139	
U 089	Both	477.4	478.3	65.81	2	33	140	

** Planning level cost estimates were developed for Tier 1 candidate locations only. Cost Estimates developed based on typical per-mile/foot construction costs for widening and are expressed in 2015 dollars and have not been field verified. Costs associated with acquiring right-of-way, widening culverts, and environmental mitigation are not included in estimates. Due to topographical or other physical constraints adjustment factors may need to be applied to the cost estimates to account for increased construction costs. During project implementation, the costs for each project may vary; therefore, during the design phase a detailed analysis should be performed to determine actual costs. Unless otherwise noted, the recommended projects are not yet funded.*

Table 5.2: Two-Lane Highways - Ranking of Priority Candidate Locations in Flagstaff District (Continued)

Route	Direction	BMP	EMP	Total Points	Tier Level	District Rank	Statewide Rank	Cost Estimate*
U 180	Both	218.0	220.0	65.73	2	34	143	
U 180	Both	220.0	223.2	65.37	2	35	149	
S 179	Both	302.0	304.5	64.48	2	36	164	
U 089	Both	550.0	552.0	64.21	2	37	172	
U 160	Both	318.0	320.0	64.16	2	38	177	
U 089	Both	554.0	556.8	63.79	2	39	184	
U 180	Both	223.2	226.0	63.79	2	40	185	
U 160	Both	316.0	318.0	63.78	2	41	186	
S 179	Both	299.0	302.0	63.63	2	42	189	
U 089	Both	552.0	554.0	63.60	2	43	191	
U 160	Both	311.0	314.0	61.32	2	44	224	
UA089	Both	590.0	592.0	59.92	2	45	241	
U 160	Both	340.0	342.0	59.55	2	46	249	
U 160	Both	336.0	338.0	59.24	2	47	252	
S 098	Both	300.0	302.0	59.04	2	48	255	
U 160	Both	314.0	316.0	58.89	2	49	256	
S 098	Both	298.0	300.0	58.81	2	50	258	
U 160	Both	360.0	362.0	56.72	2	51	283	
U 160	Both	342.0	344.0	55.44	3	52	298	
U 160	Both	358.0	360.0	55.37	3	53	300	
U 160	Eastbound	356.0	358.0	54.88	3	54	304	
U 089	Both	493.1	494.1	54.57	3	55	307	
U 160	Both	352.0	354.0	54.37	3	56	311	
U 160	Both	350.0	352.0	54.16	3	57	312	
U 089	Both	519.9	521.2	53.89	3	58	314	
S 098	Both	354.0	356.0	53.24	3	59	318	
U 160	Both	344.0	346.0	51.70	3	60	324	
U 160	Both	354.0	356.0	51.51	3	61	328	
U 160	Both	346.0	348.0	51.12	3	62	329	
S 098	Both	352.0	354.0	50.75	3	63	331	

** Planning level cost estimates were developed for Tier 1 candidate locations only. Cost Estimates developed based on typical per-mile/foot construction costs for widening and are expressed in 2015 dollars and have not been field verified. Costs associated with acquiring right-of-way, widening culverts, and environmental mitigation are not included in estimates. Due to topographical or other physical constraints adjustment factors may need to be applied to the cost estimates to account for increased construction costs. During project implementation, the costs for each project may vary; therefore, during the design phase a detailed analysis should be performed to determine actual costs. Unless otherwise noted, the recommended projects are not yet funded.*

Table 5.2: Two-Lane Highways - Ranking of Priority Candidate Locations in Flagstaff District (Continued)

Route	Direction	BMP	EMP	Total Points	Tier Level	District Rank	Statewide Rank	Cost Estimate*
S 098	Both	350.0	352.0	50.57	3	64	333	
S 098	Both	328.0	330.0	49.23	3	65	341	
U 089	Both	505.7	507.1	49.03	3	66	345	
S 098	Both	318.0	320.0	48.80	3	67	348	
S 098	Both	308.0	310.0	48.61	3	68	349	
S 098	Both	348.0	350.0	48.59	3	69	350	
S 098	Both	302.0	304.0	48.58	3	70	351	
S 098	Both	342.0	344.0	48.45	3	71	356	
S 098	Both	344.0	346.0	48.35	3	72	358	
S 098	Both	330.0	332.0	48.29	3	73	360	
U 089	Both	509.2	512.2	46.43	3	74	370	
S 064	Both	284.0	286.0	43.40	3	75	374	

** Planning level cost estimates were developed for Tier 1 candidate locations only. Cost Estimates developed based on typical per-mile/foot construction costs for widening and are expressed in 2015 dollars and have not been field verified. Costs associated with acquiring right-of-way, widening culverts, and environmental mitigation are not included in estimates. Due to topographical or other physical constraints adjustment factors may need to be applied to the cost estimates to account for increased construction costs. During project implementation, the costs for each project may vary; therefore, during the design phase a detailed analysis should be performed to determine actual costs. Unless otherwise noted, the recommended projects are not yet funded.*