Appendix D
Traffic Safety Analysis Memorandum

Memorandum

Project: Red Rock Trail and Intersections, DTFH68-16-D-00007/XXXX

Author: Jacobs Engineering Group Inc. (Jacobs)

For: Federal Highway Administration, Central Federal Lands Highway Division

Date: April 2, 2020

Subject: Traffic Safety Analysis

Introduction

The Red Rock Canyon National Conservation Area (RRC NCA) is located northwest of Las Vegas, Nevada, adjacent to Nevada State Route 159 (SR 159). The Federal Highway Administration, Central Federal Lands Highway Division is conducting the Red Rock Trail and Intersection project to improve safety, increase access, and improve circulation for non-motorized users to the RRC NCA. This project aims to construct the first phase of a multi-use trail from Summerlin to the entrance at Calico Basin Road, which is approximately 5.5 miles long. In addition to the trail improvements, the project will extend existing westbound right-turn deceleration lanes on SR 159 at the Calico Basin Road and Scenic Loop Drive intersections. The current deceleration lanes do not satisfy AASHTO guidance for roadways with posted speed limits of 50 miles per hour (mph). Also, available storage in the deceleration and turn lanes could be lengthened to provide more storage when the entrance station queues extend into the SR 159 through lanes during peak visitation periods. The final component of the project is to relocate the RRC NCA entrance sign and provide designated parking adjacent to the sign.

A traffic safety analysis was conducted as part of this project to identify safety issues and countermeasures to address them. The study area for the safety analysis includes SR 159 between mile markers 10.24 and 14.92, and the five intersections within this segment of SR 159 (Figure 1). This technical memorandum documents the safety analysis and recommends countermeasures to include in the design that will enhance safety for all travel modes accessing the RRC NCA.

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Data Collection

The Nevada Department of Transportation (NDOT) provided the crash data used in this analysis. The data summarizes crashes reported by the Nevada Highway Patrol and Las Vegas Metropolitan Police Department during a 5-year period between June 1, 2013, and July 1, 2018. The data contain information about the date/time, type of crash, and the driver, roadway, and environmental conditions in effect when the crash occurred. The data locate crashes by milepost rather than latitude/longitude.

In addition to the crash records, anecdotal evidence suggests these safety issues within the study area have the potential to increase the risk of collisions, and several near-misses have been observed:

- **RRC NCA Entrance Sign.** There is no designated parking area near the RRC NCA entrance sign located on the north side of SR 159, so visitors park along the narrow shoulders and walk along the roadway to access the sign and take pictures. The visitors that park along the south side of the road also cross SR 159. A crest vertical curve located just west of the sign limits visibility of pedestrians to eastbound drivers. A sight distance analysis performed for a 55 mph travelling speed suggests there is an approximately 675-foot section along eastbound SR 159 approaching this crest for which the visibility of the sign decreases to between 300 and 475 feet. The shorter distance is about 60 percent of the recommended stopping sight distance of 495 feet for vehicles traveling at 55 mph (although the speed limit is posted at 50 mph, anecdotal evidence and crash records suggest some motorists travel at a rate higher than 50 mph along this stretch of SR 159). Within this 675-foot section, drivers would not have enough distance to come to a complete stop to avoid a pedestrian crossing the road adjacent to the sign. However, even the minimum 300-foot distance would provide some time for drivers to slow enough that a moving pedestrian would likely clear the eastbound lane. Once the eastbound vehicles pass through this 675-foot section and are closer to the crest, the visibility restrictions are eliminated. Since the vertical curve is west of the sign, the crest of this curve does not impose sight distance limitations for westbound drivers.

- **Bicycle Guidance through Intersections.** Gaps exist in the edge line pavement markings through intersections. This lack of guidance to designate the shoulder from the travel lane through intersections can sometimes result in bicyclists leaving the shoulder or having no shoulder available (adjacent to right-turn lanes) and also can result in cyclists traveling in the through lane across an intersection. Drivers are not expecting this behavior or the sudden appearance of a bicyclist in front of them. In particular, the intersection to the RRC NCA entrance station at Scenic Loop Drive does not provide guidance in the form of pavement markings to designate where bicyclists should cross the right-turn lane, causing the cyclists to mix with turning vehicles.

- **Advance Signage.** The existing signage along SR 159 approaching the Scenic Loop Drive intersection is not consistent with the Manual on Uniform Traffic Control Devices (MUTCD) guidelines for approach signage to provide appropriate warning about the upcoming intersection. Thus, drivers occasionally decelerate abruptly to turn into the entrance, and following drivers may not be prepared for this sudden change in speed. As identified in the *Red Rock Canyon Road Safety Scan* technical memorandum (CH2M HILL 2015), the size and location of RRC NCA signs adjacent to the entrance contributes to congestion and conflicts.

Crash Characteristics

The crash dataset received from NDOT was analyzed to identify characteristics and patterns associated with the most recent 5-year crash period for which data were available for the study area. A total of 70 crashes occurred within the study area during the 5-year period between July 1, 2013, and July 1, 2018, or an average of 14 per year. Severe crashes (Fatal and Injury) represented nearly 60 percent of the total crashes. The crash severity distribution was as follows:

- 3 fatal crashes resulted in 3 fatalities
- 38 injury (non-fatal) crashes resulted in 53 injuries
- 29 crashes resulted in property damage only

Four crashes involved a bicycle or a motorbike, and seven crashes involved a motorcycle. Neither pedestrians nor heavy trucks were involved in any of the reported crashes. The primary type of vehicle involved in these crashes was a passenger-type car (i.e., sedan, hatchback, coupe), which represented 78 percent of the involved vehicles.

Table 1 stratifies crashes per year by severity. Note that the values for years 2013 and 2018 represent 6 months of crash data rather than a full year. The highest numbers of injury and property damage-only crashes occurred in years 2016 and 2017. Fatal crashes occurred in 2013, 2014, and 2016.

Table 1. Crashes per Year by Severity

Crashes by Year	Fatal	Injury	Property Damage	Total
2013[1]	1	4	3	**8**
2014	1	5	3	**9**
2015	0	7	4	**11**
2016	1	12	7	**20**
2017	0	9	10	**19**
2018[1]	0	1	2	**3**
Totals	**3**	**38**	**29**	**70**

[1] 6 months of crash data

Figure 2 summarizes the reported crash history at each intersection and along roadway segments between the intersections. The box color corresponds to the highest severity outcome: green indicates property damage only; yellow indicates incapacitating injury (Type A injury), non-incapacitating injury (Type B injury), or possible injury (Type C injury); and red indicates fatality. The text shows the number of crashes by severity level and the predominant crash types.

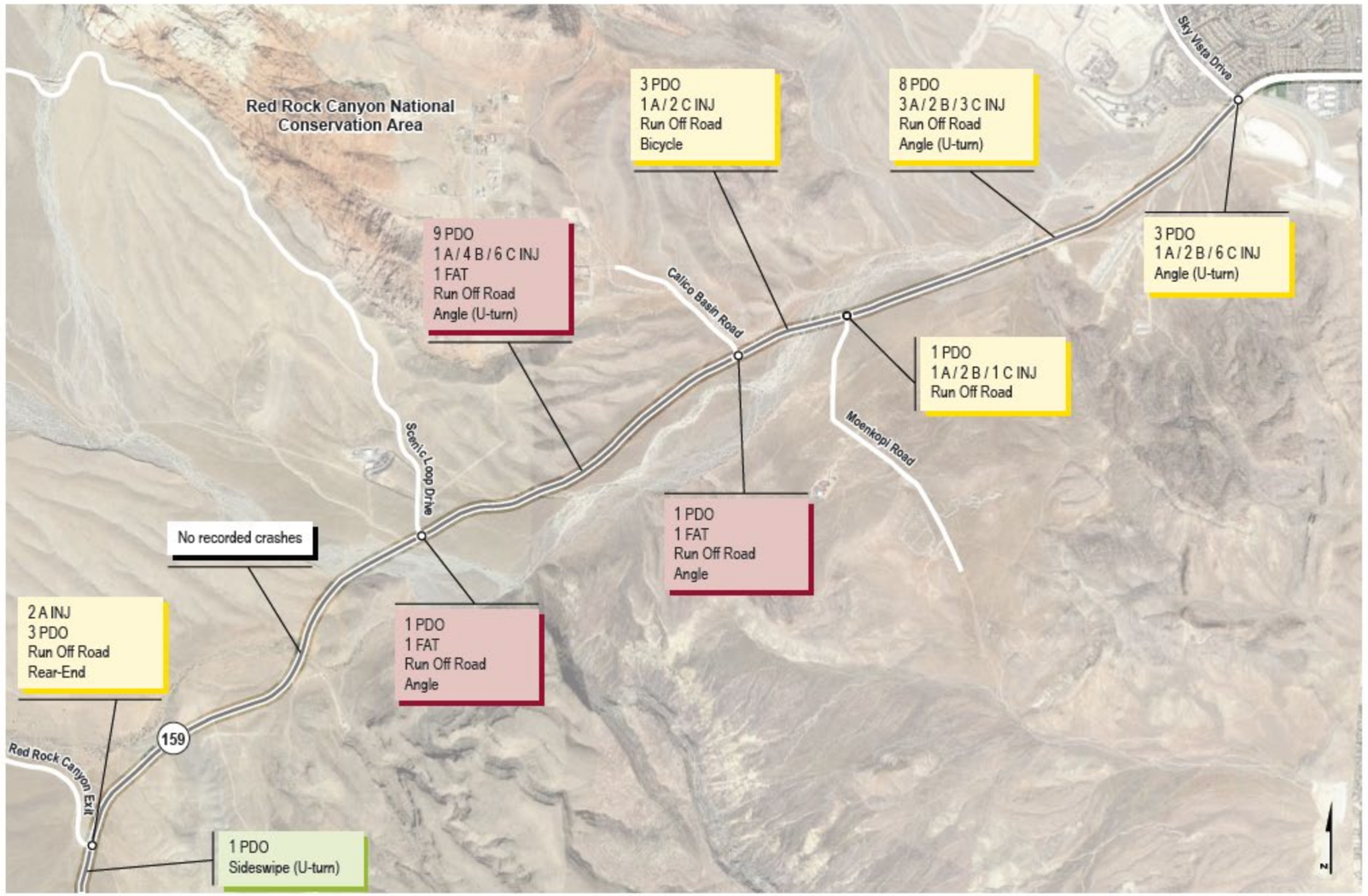

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Figure 2. Summary of Recorded Study Area Crashes

As Figure 3 shows, nearly two-thirds of the crashes occurred on roadway segments between intersections. All the study area intersections have three approaches, with the crossroads teeing into SR 159. Among the intersections, more crashes occurred at the Sky Vista Drive intersection than at the other four intersections. The intersection to exit the RRC NCA was the second highest crash location among the intersections. Although 37 percent of the crashes occurred at the intersections, these crashes represented 44 percent of the severe crashes. This indicates the likelihood of a severe crash is greater at the intersections than along the roadway segments between the intersections. Since the crash type proportions are similar between the roadway segments and the intersections, this could be attributed to a greater speed differential between vehicles in the angle type intersection crashes.

Figure 3. Total Crashes by Location and Severity

Figure 3a. Roadway Segments

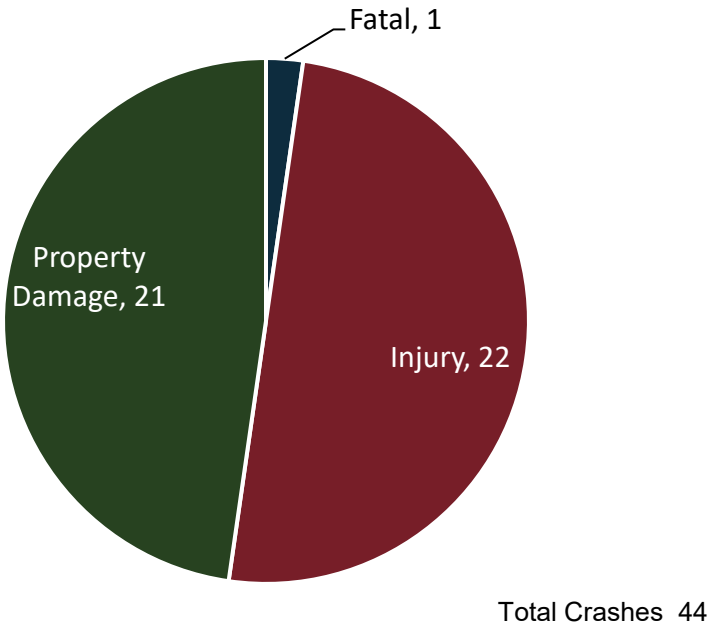


Figure 3b. Intersection with Red Rock Canyon Exit

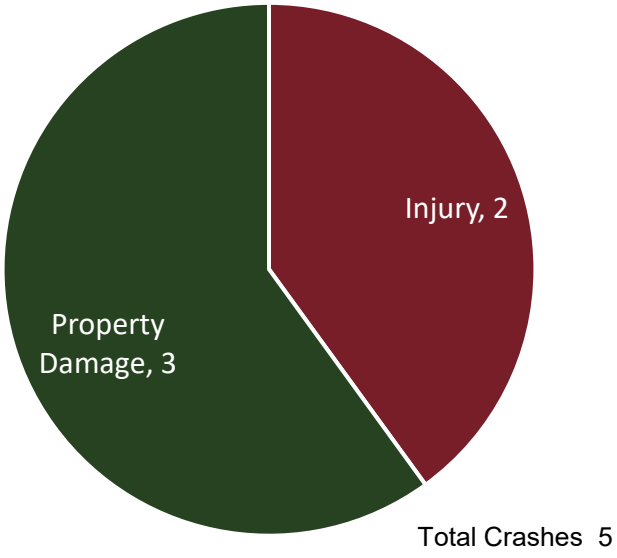


Figure 3c. Intersection with Scenic Loop Drive

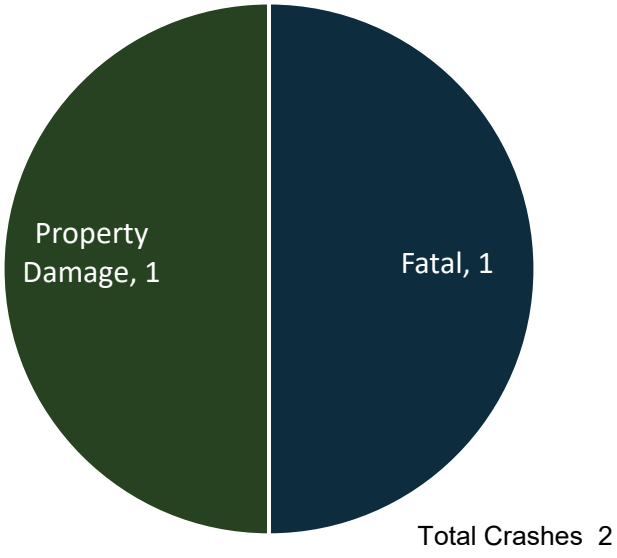


Figure 3d. Intersection with Calico Basin Road

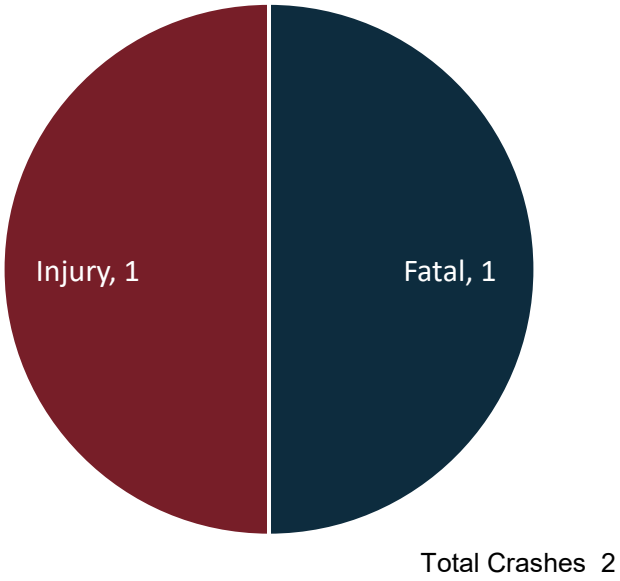


Figure 3e. Intersection with Moenkopi Road

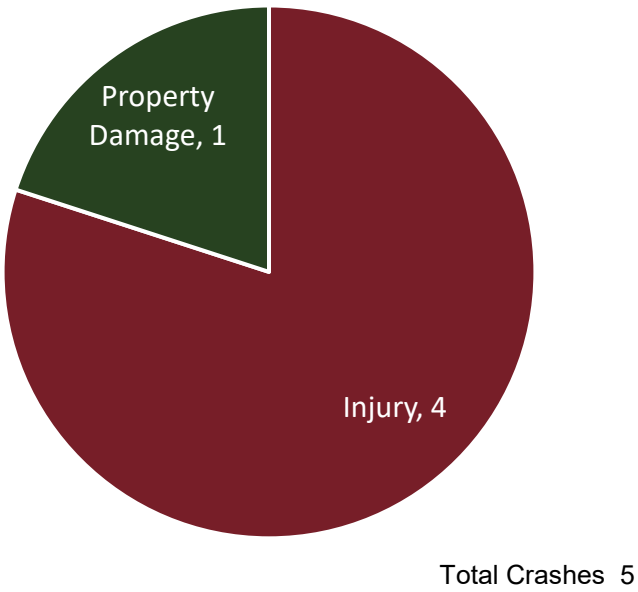


Figure 3f. Intersection with Sky Vista Drive

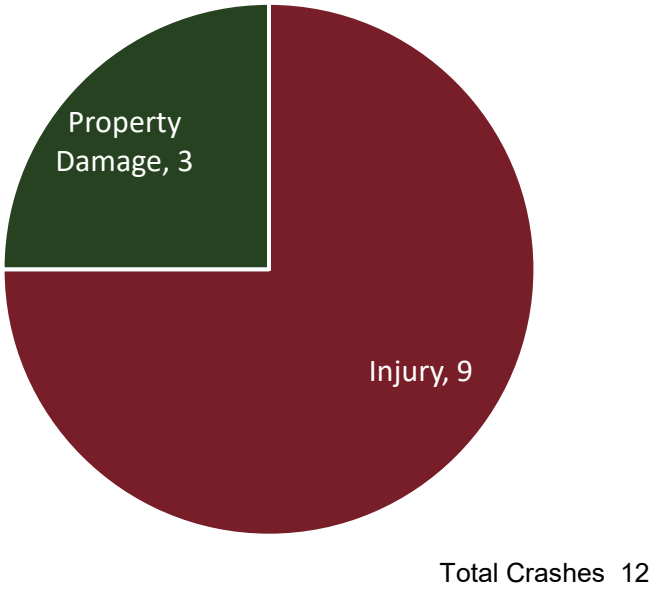
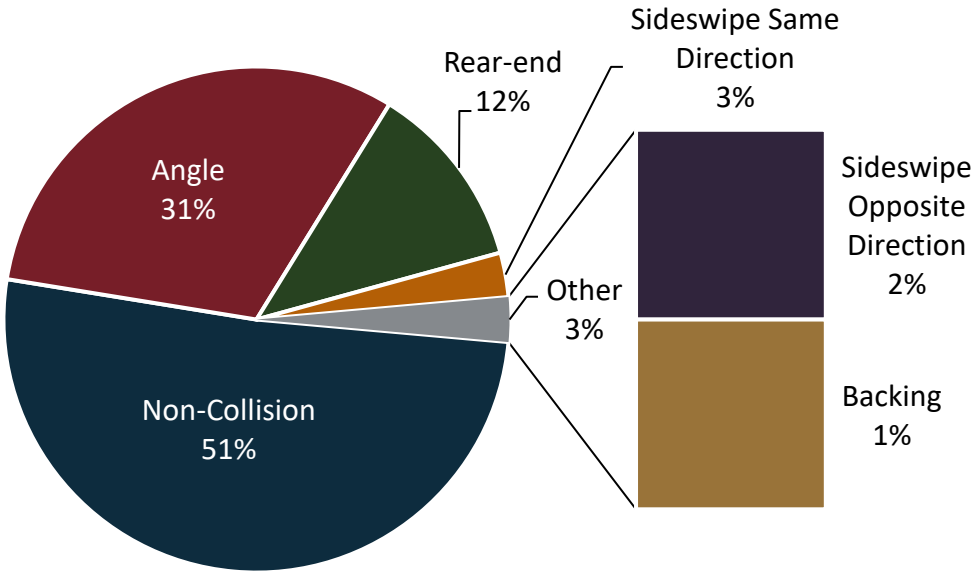


Figure 4 shows the percentage breakdown by crash type for all crashes for the study area. Representing 82 percent of the crashes, the most common crash types in the study area were non-collisions and angle crashes. This pattern was the same for both roadway segments and intersections. The non-collision crashes were primarily run-off-road crashes involving single vehicles. One-third of the non-collision crashes along roadway segments ended in a rollover, with a fatal or injury outcome for 75 percent of these eight crashes. At the intersections, one-third of the run-off-road crashes also resulted in a rollover, with a fatal or injury outcome for 80 percent of these crashes. This pattern is likely similar between the segments and the intersections because the through traffic on SR 159 is not subject to signal- or stop-control, and vehicles effectively travel through the intersections without stopping for traffic control devices. When the run-off-road crashes resulted in a fixed object being struck, the objects were posts, fences/walls, ditches, and embankments. Single-vehicle crashes accounted for 46 percent of the total crashes in the study area.

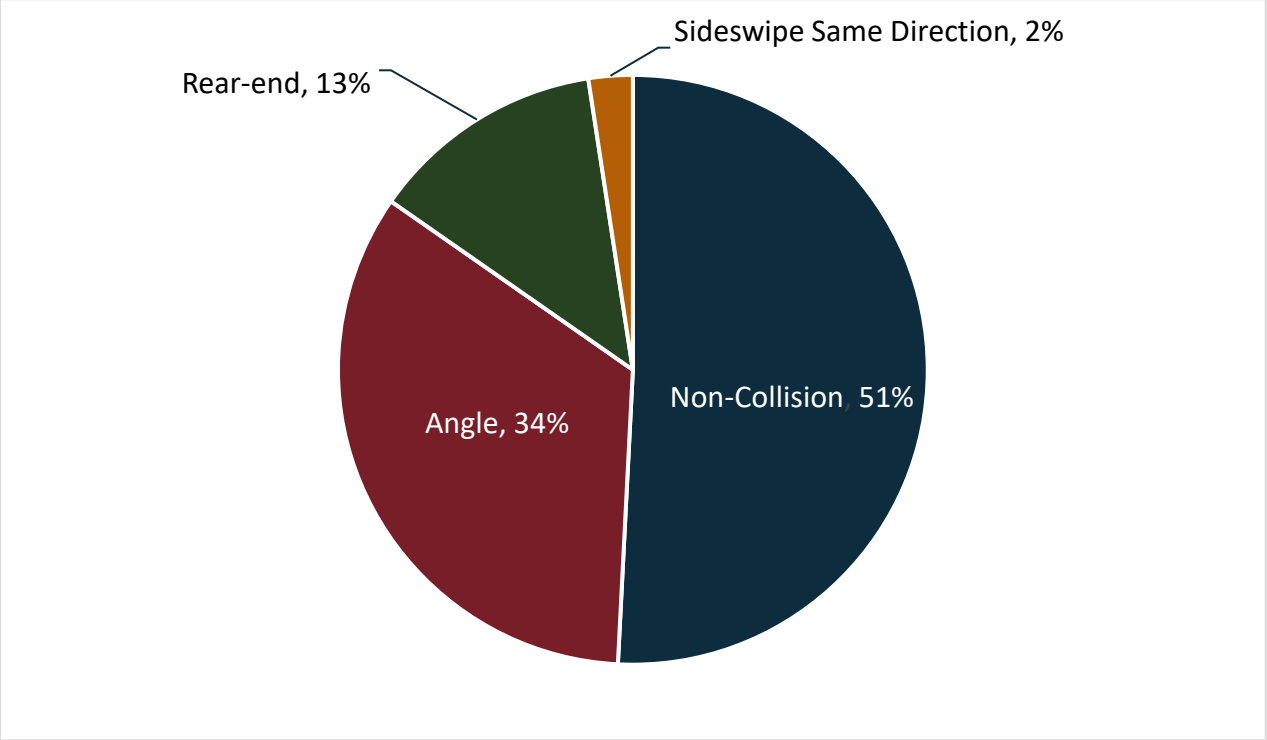
Figure 4. Type of Collision for Total Crashes



Multiple-vehicle crashes accounted for 54 percent of the total crashes in the study area. The angle crashes, the second most common crash type, occurred on both the roadway segments and at the intersections. On the roadway segments, half of these crashes occurred when a driver was executing a u-turn maneuver. Just over half of these crashes had an injury outcome. At the intersections, all the angle crashes involved left-turn or u-turn maneuvers and all but one had an injury outcome. Rear-end crashes represented the same proportion in both the roadway segment and intersection crashes. Most rear-ends that occurred on the roadway segments were attributed to driving too fast for conditions.

Figure 5 shows the percentage breakdown by crash type for fatal and injury (severe) crashes for the study area. The proportions were similar to the total crashes, with non-collision and angle crashes the primary crash types. All three fatal outcomes were non-collision crashes that ended in a rollover.

Figure 5. Type of Collision for Severe Crashes



As Figures 6a-c show, a significant majority of the crashes occurred during conditions when the roadway surface was dry, there was no precipitation noted, and daylight was the predominant lighting condition. These were the conditions for 87 percent of the total crashes. Regarding lighting condition specifically, 73 percent of the total crashes occurred in daylight conditions and 27 percent occurred in non-daylight conditions (i.e., dusk, dark with spot lighting, and dark with no lighting). Since nearly one-fourth of the severe crashes occurred in non-daylight conditions, the proportions are similar between the total crash data and the severe crash data. This similarity suggests that non-daylight conditions in the study area do not appear to increase the potential for a crash outcome to be severe.

Figure 6. Crashes by Road Surface, Weather, and Lighting Conditions

Figure 6a. Crashes by Road Surface Conditions

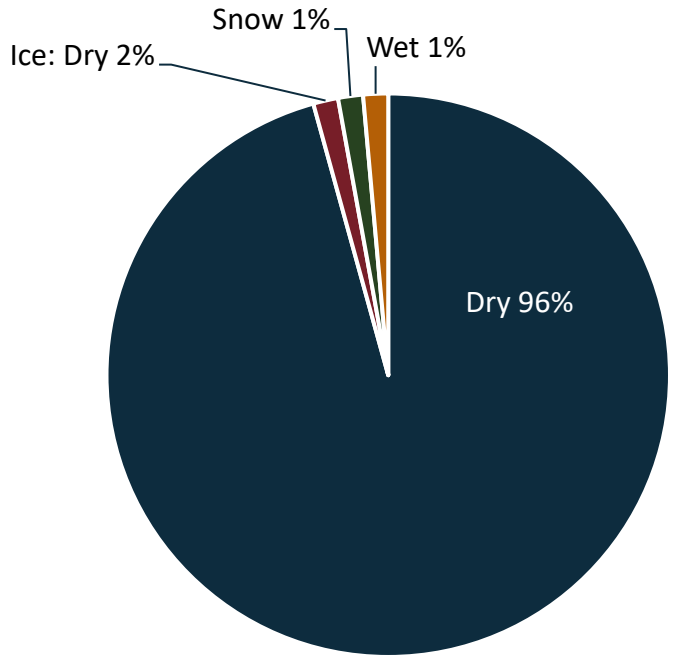


Figure 6b. Crashes by Weather Conditions

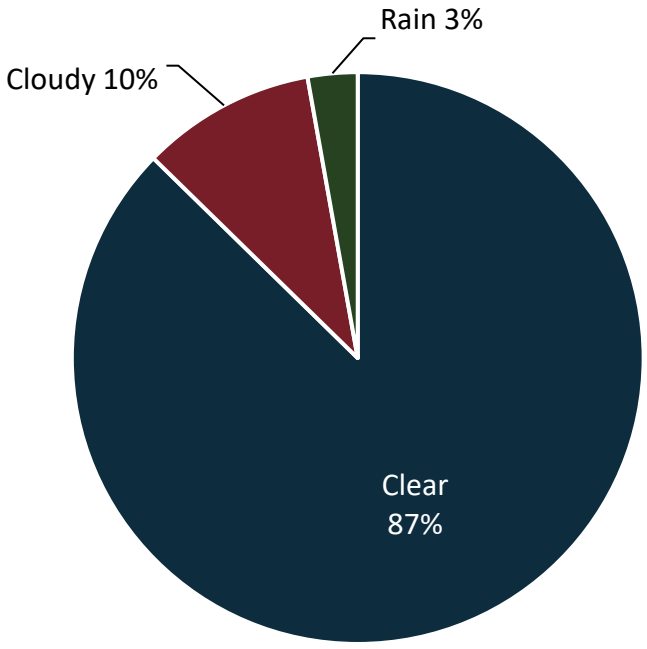
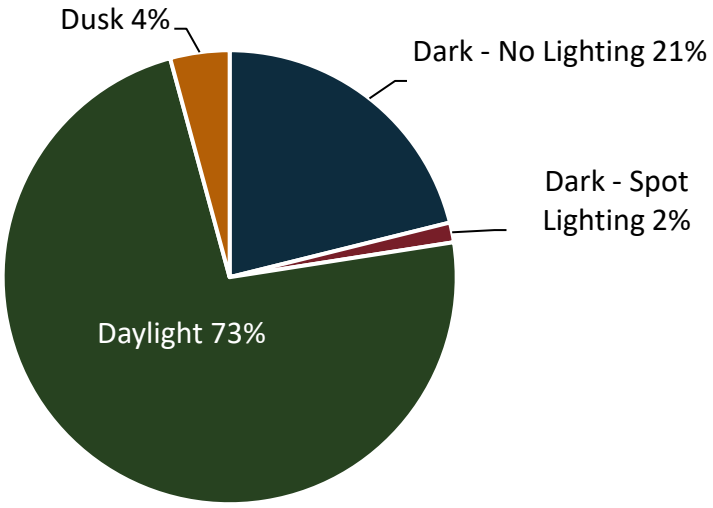
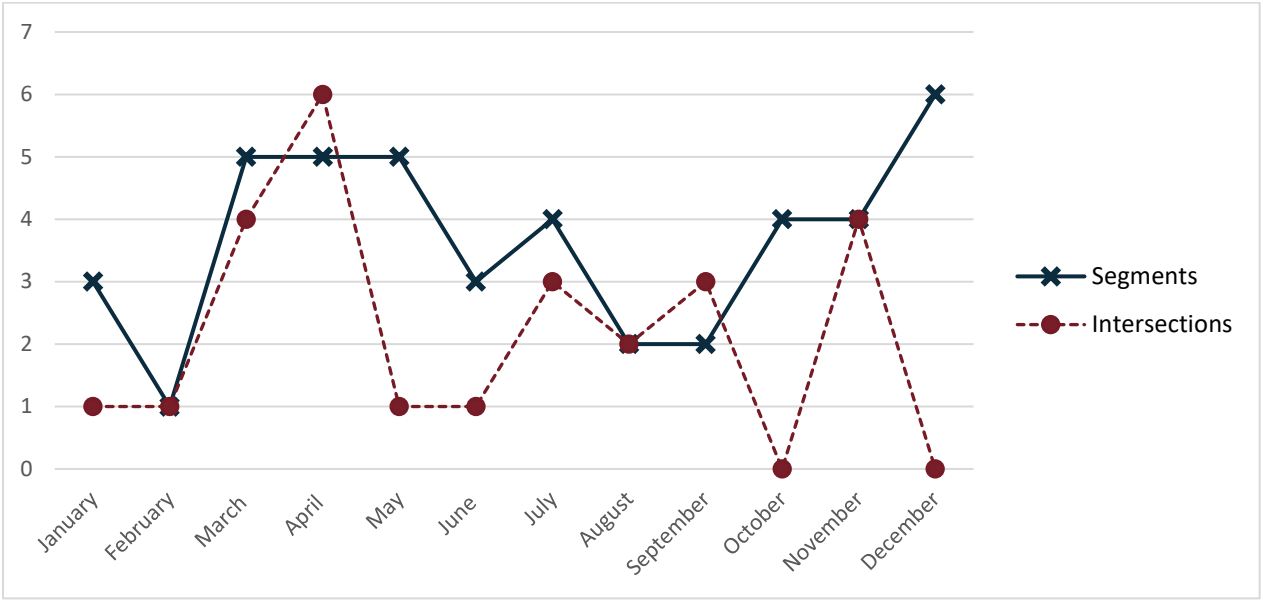


Figure 6c. Crashes by Lighting Conditions



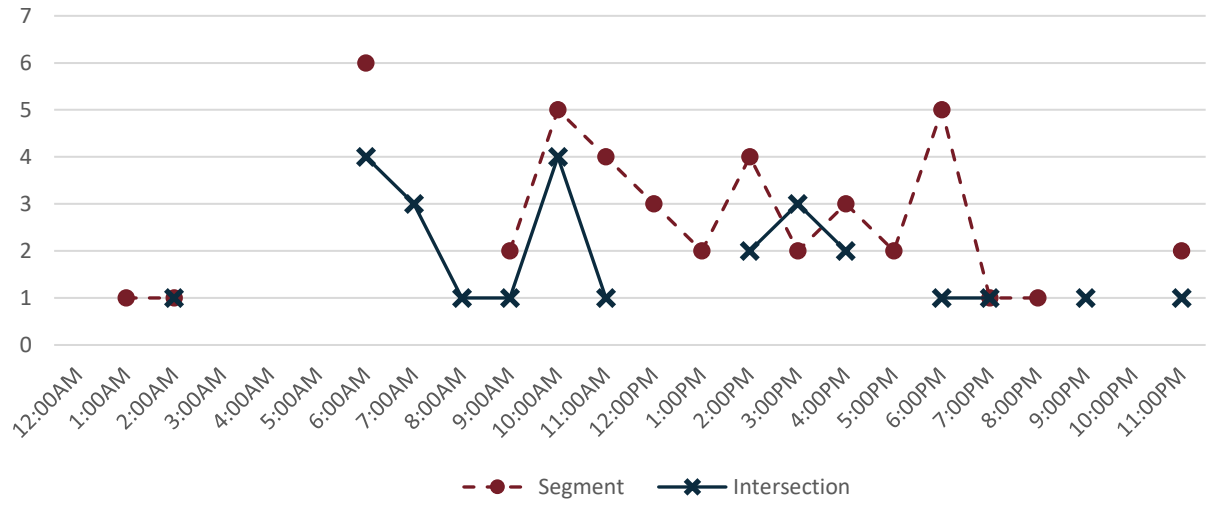
As Figure 7 shows, there was a significant monthly variation of crash frequency within the study area. More crashes occurred in April and March than any other months for both the segments and intersections. The only roadway segment crash that occurred when the surface was wet occurred in March. The other March and April crashes occurred in dry conditions. Thus, there is no discernible pattern from the crash data that suggests why crashes may have peaked in these 2 months. While the segment crashes occurred in each month, none of the intersection crashes occurred in October or December. This analysis did not consider visitation numbers, which, if higher in March and April, could have contributed to a higher crash frequency.

Figure 7. Crashes by Month



As Figure 8 shows, the crashes peaked in the morning during the 6 and 10 a.m. hours, representing 26 percent of the crashes. The majority of crashes occurred between the hours of 6 a.m. and 6 p.m., which supports the lighting condition crash factor that suggests visibility because of light condition or darkness is not a contributing factor to most crashes.

Figure 8. Crashes by Time of Day



Contributing Factors

Although multiple contributing factors were reported for most crashes, this assessment includes the first one listed, which is typically assumed to be the most prominent contributing factor. As Table 2 shows, there are 12 different contributing factors for the roadway segment crash data and 9 for the intersection crash data. The most predominant causal factors for both are failure to keep in proper lane or run-off-road. When combined with the run-off-road contributing factor, departing the travelway was the primary causal factor to 44 percent of the total crashes and 50 percent of the severe crashes. The most common secondary factors attributed to the vehicle running off the road were unsafe lane changes, over-correcting/over-steering, and drove left of center. Excessive speed does not appear to be a significant contributing factor to the run-off-road crashes per the data; however, speed is typically an issue when over-correcting/over-steering leads to loss of control and the vehicle departing the travelway. Most of the crashes with driving too fast as the primary contributing factor resulted in a severe outcome in terms of crash severity.

Table 2. Reported Contributing Factors to Crashes

Contributing Factors	Roadway Segments Total	Roadway Segments Severe	Intersections Total	Intersections Severe
Disregarded traffic signs, signals, markings	4	3	0	0
Driving too fast for conditions/exceeded authorized speed limit	5	4	4	4
Drove left of center	1	1	0	0
Failed to yield right-of-way	1	1	4	3
Failure to keep in proper lane or running off road	9	7	6	4
Followed too closely	1	0	1	1
Made an improper turn	8	2	4	3
Other improper driving	1	0	1	1
Over-steering/over-correcting	3	1	0	0
Ran off road	4	1	1	0
Unknown or not stated	5	3	4	2
Unsafe backing	1	0	0	0
Totals	**43[1]**	**23**	**25[1]**	**18**

[1] One roadway and one intersection crash were coded as hit and run, which is not a contributing factor. Therefore, the totals do not equal the number of roadway segment and intersection crashes reported in this memorandum.

Driver Condition

The condition of the driver at the time of the crash was reported as normal for most of the crashes. As Table 3 shows, alcohol/drug involvement was the second most common driver condition. These crashes primarily resulted in a severe outcome.

Table 3. Driver Condition at Time of Crash

Driver Condition	Roadway Segments Total	Roadway Segments Severe	Intersections Total	Intersections Severe
Apparently normal	29	16	16	11
Alcohol/drug involvement	6	4	4	4
Illness/illness with drug involvement	2	1	0	0
Inattention, distracted, other improper driving	2	0	1	0
Unknown or not stated	5	3	5	3
Total	**44**	**24**	**26**	**18**

Bicycle and Motorcycle Crashes

Four crashes involved a bicycle or a motorbike, representing 6 percent of all crashes. All of these resulted in an injury. Two of the crashes occurred when a vehicle traveling straight departed their lane, and one occurred when a van driver was executing a u-turn. The fourth crash occurred when the bicyclist collided with a parked car. Seven, or 10 percent, of all crashes involved a motorcycle, and all resulted in a fatality or injury. Most of these were single-vehicle crashes in which the motorcyclist ran off the road. One of the two multi-vehicle motorcycle crashes resulted when a passenger-car driver was executing a u-turn at an intersection and ran into the motorcyclist; the other occurred when the motorcyclist crossed the centerline.

Fatal Crashes

Three fatal crashes occurred during the 5-year analysis period. All were single-vehicle crashes and resulted in three fatalities. All occurred in dark unlighted conditions. Two of the crashes involved passenger vehicles whose drivers were exceeding the authorized (posted) speed limit and departed their travel lane, ultimately resulting in a rollover. One of these occurred in the rain on a wet roadway surface when the driver crossed the centerline and over-corrected, ultimately running off the road and rolling over. The other occurred on dry pavement with drug and alcohol involvement listed as the driver condition at time of crash. The third fatal crash involved a motorcycle departing the road on a roadway surface that was reported as ice: dry on a clear September night. This analysis assumes that the intent of this entry was to convey that the road surface was mostly dry with icy patches. Per the crash data, it appears that the motorcyclist was traveling too fast for conditions and

hit an icy patch, then proceeded to cross the centerline, strike a ditch, and rollover, ultimately colliding with a tree. A contributing factor was not included, but the data suggest driving too fast for the roadway conditions.

Crash Pattern Analysis

The crash characteristics provide information on the nature of the crashes within the study area. Analyzing the specific locations of the crashes can show if and where a significant number of crashes is clustered. These two analyses often show prevailing patterns, which can suggest areas to focus on to determine strategies that could improve safety.

Cluster Analysis

A cluster is a location at which several crashes with similar characteristics occur. A hot spot represents clusters with high crash frequencies. For the roadway segments between intersections in the study area, there were no crash cluster locations because the crashes generally occurred along the length of each segment. There were a couple discernible patterns at two of the study area intersections. This cluster analysis also included the deceleration lane and sign locations that are included in the project. The following summarizes the findings of the cluster analysis:

- **Red Rock Canyon Exit Intersection**: Two rear-end crashes occurred when eastbound drivers collided with vehicles that were stopped in the lane. Both occurred during normal conditions (daylight, dry road surface, clear weather) with reported driver factor of apparently normal. Although the crossroad is one-way and vehicles cannot turn into the park at this location from SR 159, a roadside parking area that is adjacent to this intersection can be accessed from the highway. These rear-end crashes may have occurred if a vehicle was stopped in the eastbound through lane while the driver was waiting for a gap through which to turn left into the parking area. Two of the five crashes appear to involve westbound drivers attempting to turn right from SR 159 into this parking area and running off the road and colliding with a fixed object.

- **Sky Vista Drive Intersection**: One-third of the twelve crashes at this intersection involved westbound drivers executing a u-turn in the intersection. All occurred during normal conditions (daylight, dry road surface, clear weather) with reported driver factors of apparently normal. The contributing factors were improper driving or improper turn.

- **Deceleration Lanes**: This project includes the extension of existing right-turn deceleration lanes on SR 159 at the Calico Basin Road and Scenic Loop Drive intersections. One angle crash was reported at the Calico Basin Road intersection in which the contributing factor was reported as a driver making an improper turn. The crash report states the driver was traveling westbound and turning left when they struck a pickup truck also traveling west; because of the geometry of this tee intersection, it is likely that the at-fault driver was traveling eastbound and did not select

an adequate gap through which to turn. Likewise, the one multi-vehicle crash reported at the Scenic Loop Drive intersection was an angle crash in which the eastbound driver made an improper turn while executing a left-turn maneuver and struck a vehicle travelling straight in the westbound lane. Thus, neither of these crashes appear to be related to the length of the existing right- or left-turn deceleration lanes. Although the reported crash history does not suggest the length of the westbound right-turn deceleration lanes is currently or has historically been an issue, improving the lengths of these two deceleration lanes to match recommended guidance could reduce the potential for rear-end collisions to occur at these two intersections in the future.

- **RRC NCA Entrance Sign**: The sign is currently located at approximately mile marker 13.93. There are no crashes coded to a location within the vicinity of this mile marker. However, as discussed in the Data Collection section, the potential for pedestrian collisions and parking related crashes exists because visitors park adjacent to the travel lanes and walk along the road to access the sign.

Diagnosis of Patterns

The analysis and diagnosis of the crash dataset suggests patterns for crashes in the study area. The following issues surfaced repeatedly during the analysis and serve to focus the discussion of countermeasures that may reduce these types of crashes:

- **Run-Off-Road**: The most prevalent crash occurrence in this study area was a single vehicle departing the travel lane and running off the road, typically called a road departure crash. Vehicles departed the road to the right by crossing the adjacent shoulder and to the left after crossing the centerline and traveling across the opposite direction lane and shoulder. Although roadway geometry information is not included in the crash dataset, it appears that roadway curvature is not a primary contributing factor to these crashes since reported crashes were located in what can be considered as tangent sections along the length of the study area. Although road surface and weather conditions to not appear to be contributing factors to these crashes, darkness conditions do appear to be a contributing factor because more than half of these crashes along the roadway segments did occur in non-daylight lighting conditions. Over-correcting was cited as a contributing factor more often than excessive speed, indicating drivers did not recover in an appropriate manner once their vehicle started drifting out of the travel lane.

- **U-turn Maneuvers**: A total of 13 crashes occurred as a result of a driver attempting a u-turn maneuver—6 at intersections and 7 along roadway segments. The crash data attributed these all as the drivers making improper turns. Only two of these crashes occurred in darkness conditions, so light condition was not a primary contributing factor. Based on the proximity to the Scenic Loop Drive intersection and the reported direction of travel, five of the seven

roadway segment u-turn crashes may have resulted because the eastbound drivers errantly passed the intersection to enter Red Rock Canyon. Four of the u-turn-related intersection crashes occurred in the westbound direction on Sky Vista Drive. A review of Google Earth imagery dated 2018 shows a regulatory no u-turn sign in place for westbound traffic, indicating the sign to prohibit u-turn maneuvers was in place for at least a portion, if not all, of the study period.

Hot Spots

The crash data suggests the study area hot spots are the SR 159 intersections with Sky Vista Drive and Red Rock Canyon Exit along with the segment of SR 159 between Calico Basin Road and the RRC NCA entrance at Scenic Loop Drive. As shown in Figure 2, a total of 21 crashes occurred along this segment during the 5-year analysis period, which was greater than the other segments. Half of these had a severe outcome and one fatality occurred. The crashes were evenly distributed between single-vehicle and multiple-vehicle crashes. Angle collision was the predominant type of multiple-vehicle crash; most of these were the u-turns noted in the Diagnosis of Patterns section plus one crash coded to an improper left turn. As most of these drivers were travelling westbound and would not have yet reached the park entrance, this pattern does not appear to be related to drivers attempting to access the RRC NCA. The single-vehicle crashes all occurred when the driver departed the travel lane and ran off the road.

Recommended Countermeasures

This analysis has developed recommendations to address safety issues identified through this current data-driven analysis, review of the *Red Rock Canyon Road Safety Scan* technical memorandum (CH2M HILL 2015), and review of the *Red Rock Canyon Trail and Intersection Project Scoping Report* (Jacobs 2019). The recommendations are consistent with the context of RRC NCA where possible and provide potential safety improvements for RRC NCA visitors and the general travelling public. Although SR 159 is adjacent to the RRC NCA and not within it, traveling along the highway is part of the visitation experience because the area is visible from the highway; therefore, context-sensitive solutions for crash issues are appropriate. Furthermore, location of the proposed trail within the RRC NCA necessitates context-sensitive design elements. The recommendations are countermeasures that have proven to be effective at reducing crashes based on national best practices. Two sets of recommendations are offered—one set provides countermeasures that can be accomplished within the scope of the Red Rock Trail and Intersection project while the other set provides recommendations appropriate for inclusion in future SR 159 improvement efforts by others.

Once the preferred locations for the multi-use trail and RRC NCA sign parking lot are selected, the Red Rock Trail and Intersection project will proceed forward into preliminary design of the trail, deceleration lane, and sign parking area improvements. The trail will be separated from SR 159,

which will reduce conflicts identified through anecdotal evidence and crash data. This safety analysis recommends the following countermeasures be considered for inclusion in the design to address identified crash issues and enhance safety for motorists navigating through the study area:

- **Multi-use Trail**: Relevant regulatory and warning signs should be provided in addition to pavement markings along the trail and at roadway crossings such as Calico Basin Road. Centerline pavement markings will be beneficial to separate opposing directions and enhance safety on this two-way trail. The signs and markings should follow the guidance in the latest edition of the MUTCD. Signs and pavement markings to provide guidance to drivers and other users on the cross roads would reduce the potential for collisions between vehicles and trail users crossing the road.

- **Deceleration Lanes**: The design of the deceleration lanes should include taper and deceleration lengths appropriate for a 50-mile-per-hour posted speed limit in addition to adequate storage length for queued vehicles waiting for a gap in oncoming traffic through which to turn. Provision of adequate deceleration lane lengths would permit deceleration to primarily occur separate from the through lane and thereby reduce conflicts and turbulence in the traffic stream and the potential for rear-end collisions. The pavement markings associated with the channelizing line, centerline, turn arrows, and bike lane should be high visibility pavement markings to improve visibility in low-lighting conditions.

- **RRC NCA Sign Parking Area**: If the proposed parking area will not be accessed from an existing road that intersects SR 159, the location for the sign and formalized parking area should be selected such that the access to the lot is a defined entry/exit point that tees into SR 159 at a location with adequate intersection sight distance. Left-turn and right-turn deceleration lanes should be provided per NDOT standards and anticipated left-turn storage needs. Advance warning signs and high-visibility pavement markings will help drivers navigate through the intersection and access the parking area. Provision of parking in a defined lot would reduce parking along SR 159 and reduce the potential for pedestrian-vehicle collisions along SR 159.

- **Advance Intersection Warning Signs**: Providing warning signs with supplementary plaques would alert drivers to an upcoming intersection and the possibility of traffic conflicts because of slowing or turning vehicles. Providing the crossroad name on a supplementary plaque would supply additional driver guidance and reduce the likelihood of drivers slowing to read a street name sign or making sudden stopping/turning maneuvers at the intersection. These signs help provide clear guidance to motorists and could reduce the potential for rear-end collisions. The Road Safety Scan recommended these warning signs and modifications to the existing guide signs to provide "…sound guidance to motorists that are unfamiliar with the park" (CH2M HILL 2015). Furthermore, the u-turn maneuvers that were a prevailing crash pattern in this crash data set would likely be reduced with this additional guidance for drivers. Installation of no u-turn signs would not likely be as effective at these intersections because there is no median or

signal mast arm on which to install the signs in the middle of SR 159; u-turn regulatory signs are not typically installed on the right side of the road.

- **Bicycle–Vehicle Interactions**: The potential for crashes involving both bicycles and vehicles would be reduced if cyclists could choose to ride on the new trail rather than SR 159. Separating the modes would also reduce the severity of crashes; the dataset indicates that the crashes involving bicyclists had severe injury outcomes (Type A and Type B Injury crashes).

The following safety countermeasures have the potential to address some of the identified crash issues but are outside the scope of this project. These are offered as recommendations to be considered in the future when improvements for SR 159 are being discussed and designed:

- **Run-Off-Road**: These countermeasures increase the likelihood that drivers will maintain their vehicle on the travelway:
  - Centerline rumble strips (noise and vibration alert the driver that they have drifted out of their lane)
  - Edge line rumble stripes (the grooves are located in the edge line marking rather than in the shoulder area to prevent conflicts for bicyclists travelling in the shoulder)
  - Safety edge along outside shoulder (reduces the potential for a vehicle to roll over if a driver veers off the pavement and over corrects or steers the vehicle while attempting to re-enter the roadway)
  - Standard outside shoulder widths (provide more space for a driver to correct an errant vehicle before driving off the pavement)
- **Lighting Condition**: These countermeasures assist to illuminate the roadway and enhance visibility during low-light conditions:
  - Roadside delineators
  - High-visibility pavement markings
- **Driver Guidance**: These countermeasures assist driver navigation and reduce driving complexity:
  - Locate intersection warning signs to provide adequate distance for drivers to comprehend the messaging and react as appropriate
  - Separate guide signs and regulatory and warning signs to allow adequate distance/time to comprehend the messaging

  - Locate warning signs so there is adequate visibility distance

- **Bike Lane on SR 159**: In the event that some bicyclists will travel along SR 159 to destinations other than RRC NCA, widening the road would provide space for a designated bike lane to separate vehicles and bicycles. Signs and markings per the MUTCD should be provided to delineate the bike lane and provide guidance for bicyclists and motorists where the bike lane is adjacent to right-turn deceleration lanes and crossing at intersections. The presence of a bike lane adjacent to the right-turn deceleration lanes also serves to shift the decelerating vehicles partially out of the sight line of drivers on the cross-roads, improving visibility of oncoming traffic.

References

CH2M HILL. 2015. *Red Rock Canyon Road Safety Scan*. Technical Memorandum. March.

Federal Highway Administration (FHWA). 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition, Revised May 2012.

Jacobs. 2019. *Red Rock Trail and Intersections Scoping Report*. NV FLAP 500(1).

Nevada Department of Transportation (NDOT). 2019. Spreadsheet of crash data. SR 159 SEG.MM 10.24 – 14.92 INTERSECTIONS.xls. September.