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Review of California's Rural Intersection Crashes:

Application of Methodology for Identifying Intersections for Intersection Decision Support (IDS)

Report #8 in the Series: Toward a Multi-State Consensus on Rural Intersection Decision Support

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The Intersection Decision Support (IDS) research project is sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), whose objective is to improve intersection safety. The Minnesota team's focus is to develop a better understanding of the causes of crashes at rural unsignalized intersections and then develop a technology solution to address the cause(s).

In the original study, a review of Minnesota's rural crash records and of past research identified poor driver gap selection as a major contributing cause of rural intersection crashes. Consequently, the design of the rural IDS technology has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the available gaps in the traffic stream to the driver.

In order to develop an IDS technology that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation initiated a State Pooled Fund study, in which nine states are cooperating in intersection-crash research. This report documents the crash analysis phase of the pooled fund study for the State of California.

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Review of California's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection Decision Support (IDS)

Report #8 in the Series: Toward a Multi-State Consensus on Rural Intersection Decision Support

Final Report

Prepared by

Howard Preston, P.E.
Richard Storm, P.E., PTOE™
CH2M HILL

Max Donath
Craig Shankwitz
ITS Institute
University of Minnesota

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Published by

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

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- California
- Georgia
- Iowa
- Michigan
- Minnesota
- Nevada
- New Hampshire
- North Carolina
- Wisconsin

We would also like to especially acknowledge several individuals at the California Department of Transportation (CALTRANS) who played key roles in the analysis of California intersections and development of this report. We would like to thank Pete Hansra, Chief Traffic Engineering Research, and Debbie Silva, Research Analyst, who provided traffic information, oversaw the selection process and coordinated the transfer of crash records. The research team also wishes to acknowledge Tom Schriber, Branch Chief, HQ Traffic Safety Investigations; and staff from District 7 and District 9 who assisted in the collection of information for the final candidate locations.

Finally, we wish to acknowledge the assistance provided by Ginny Crowson of the Minnesota Department of Transportation (Mn/DOT), who serves as technical manager of the pooled fund project, the late Jim Klessig of Mn/DOT, who previously served as administrative liaison of the pooled fund, and Deb Fick, who serves as the administrative liaison.

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Executive Summary

The objective of the Intersection Decision Support (IDS) research project, sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), was to improve intersection safety. The Minnesota team's focus was to develop a better understanding of the causes of crashes at rural unsignalized intersections and then develop a solution to address the cause(s).

In the original study, a review of Minnesota's rural crash records and of past research identified poor driver lag selection as a major contributing cause of rural intersection crashes. Consequently, the design of the rural IDS system has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information to the driver when the lags in the traffic stream are unsafe.

Based on the Minnesota crash analysis, one intersection was identified for instrumentation (collection of driver behavior information) and the IDS vehicle surveillance system was deployed and tested. Preliminary Driver Infrastructure Interfaces (DII) designs were also tested in a driving simulator at the University of Minnesota.

To develop an IDS system that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation (Mn/DOT) initiated a State Pooled Fund study, in which nine states are cooperating on intersection-crash research. The participating states are:

- California
- Georgia
- Iowa
- Michigan
- Minnesota
- Nevada
- New Hampshire
- North Carolina
- Wisconsin

The first facet of this pooled fund project is a review of intersection crash data from each participating state, applying methods developed in previous IDS research. The crash data will be used to understand rural intersection crashes on a national basis, and to identify candidate intersections for subsequent instrumentation and study. The second facet is to instrument one candidate intersection in each participating state, as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. States choosing to instrument intersections will be well positioned to reap the benefits of the new Cooperative Intersection Collision Avoidance System (CICAS) research funded by the United States Department of Transportation (USDOT) and Mn/DOT. The CICAS Stop Sign Assist Program will investigate the human factors and technical considerations associated with the proposed IDS approach used to communicate with the driver at the intersection. A planned Field Operational Test will be designed to evaluate the performance of these systems.

Of the participating states, California was the final state for which the crash analysis was performed. Of the nine states involved in this study, six states focused on rural, four-lane expressways (i.e., divided roadways). These six states included California, Iowa, Minnesota, Nevada, North Carolina and Wisconsin. The remaining three states, Georgia, Michigan, and New Hampshire, instead focused on rural intersections of two-lane highways (i.e., undivided).

Review of California's Intersections

This report documents the initial phase of the pooled fund study for the State of California. The crash analysis focused on thru-STOP intersections along expressways with a US or State Highway route designation in rural California. The California Department of Transportation (CALTRANS) initially selected four rural expressway corridors for this study. The four selected corridors were:

- US 101 in Humboldt County (from reference point 80.260 to 83.920)
- US 101 in Ventura County (from reference point 40.891 to 41.471)
- State Route 99 in Merced County (from reference point 1.560 to 8.440)
- State Route 86 (spur) in Riverside County (from reference point R3.484 to R13.110)

Within the four corridors, CALTRANS provided crash record information for 23 intersections. For State Route (SR) 86S, crashes were from October 1, 2003 through September 30, 2006. Crashes from July 1, 2001 through June 30, 2006 were provided for the remaining three corridors. From the 23 intersections, the crash summary statistics provided by CALTRANS identified two locations along SR 86S where there was a high crash frequency along with a high frequency of broadside crashes — the target crash type. However, unusual geometry and recent safety improvement projects (i.e., traffic signal installation) made it unnecessary to include this corridor in the detailed crash analysis. From the remaining locations, three locations stood out as having a combination of high frequency of total crashes and a high frequency of broadside crashes, and were included in the detailed analysis. After starting the detailed crash analysis, one of these intersections had to be eliminated because many of the broadside crashes were actually determined to be a left-turn head-on crash after the investigating officer's narrative was reviewed — the California crash records system does not distinguish between a right angle crash (involves one vehicle from both the major and minor roads) and a left-turn head-on crash (involves two vehicles on the major road, one of which is turning left). The two remaining intersections that best fit the study's criteria were:

1. US 101 & Ocean Drive in Ventura County
2. US 101 & La Conchita Road in Ventura County

These two locations on US 101 are approximately one-half mile apart, where US 101 runs between the Pacific coast and a railroad line. After reviewing the field conditions and available right-of-way with the District, it was determined that there wouldn't be sufficient room to safely place the mobile vehicle surveillance system, which includes radar units, lidar, generators and an equipment trailer. However, this does not mean there wouldn't be room for the installation of a permanent and final IDS system. Following this decision, little time remained before the mobile system had to be taken down from the previous site and moved to a California intersection. Therefore, CALTRANS worked with the Districts to identify and directly select a rural intersection that had a known safety issue and sufficient room for the equipment. This led to the selection of US 395 and Gill Station Coso Road. The conditions at the intersection showed that CALTRANS had previously installed several safety countermeasures at the intersection, including a median acceleration lane, a free right, intersection lighting, warning signs mounted under STOP signs, and LED flashers around the face of STOP signs. Despite these safety improvements, a review of the crash data at this intersection revealed that five crashes occurred in three years, but all five crashes were related to lag selection. Furthermore, the crash severity was unusual since three crashes resulted in an injury and two crashes resulted in a fatality.

1. Project Background

The objective of the Intersection Decision Support (IDS) research project, sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), was to improve intersection safety. The Minnesota team's focus was to develop a better understanding of the causes of crashes at rural unsignalized intersections and then develop a solution to address the cause(s).

In the original study, a review of Minnesota's rural crash records and of past research identified poor driver lag selection as a major contributing cause of rural intersection crashes. Consequently, the design of the rural IDS system has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the safety of the lags in the traffic stream to the driver.

Based on the Minnesota crash analysis, one intersection was identified for instrumentation (collection of driver behavior information) and the IDS vehicle surveillance system was deployed and tested. Also underway, alternative Driver Infrastructure Interfaces (DII) designs are being tested in a driving simulator at the University of Minnesota.

In order to develop an IDS system that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation (Mn/DOT) initiated a State Pooled Fund study, in which nine states are cooperating on intersection-crash research. The participating states are:

- California
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The first facet of this pooled fund project is a review of intersection crash data from each participating state, applying methods developed in previous IDS research. The crash data will be used to understand rural intersection crashes on a national basis, and to identify candidate intersections for subsequent instrumentation and study. The second facet is to instrument one candidate intersection in each participating state, as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. States choosing to instrument intersections will be well positioned to reap the benefits of the new Cooperative Intersection Collision Avoidance System (CICAS) research funded by the United States Department of Transportation (USDOT) and the Mn/DOT. The CICAS Stop Sign Assist Program will investigate the human factors and technical considerations associated with the proposed IDS approach used to communicate with the driver at the intersection. A planned Field Operational Test will be designed to evaluate the performance of these systems.

This report documents the initial phase of the pool fund study for the State of California. In the following sections are a description of the crash analysis performed for California and a recommendation of an intersection as a test site for studying driver entry behavior. The data acquired from this site and from other selected intersections across the country will provide information needed to design an IDS system for national deployment.

1.1. Typical Countermeasures for Rural Intersections

A typical crossing path crash (i.e., right angle crash) at a rural unsignalized intersection is most often caused by the driver's (on a minor street approach) inability to recognize the intersection (which consequently results in a run the STOP sign violation), or his/her inability to recognize and select a safe lag in the major street traffic stream.

Traditional safety countermeasures deployed at rural high crash intersections include:

- Upgrading traffic control devices
  - Larger STOP signs
  - Multiple STOP signs
  - Advance warning signs and pavement markings
- Minor geometric improvements
  - Free right turn islands
  - Center splitter islands
  - Off-set right turn lanes
- Installing supplementary devices
  - Flashing beacons mounted on the STOP signs
  - Overhead flashing beacons
  - Street lighting
  - Transverse rumble strips

All of these countermeasures are relatively low cost and easy to deploy, but are typically designed to assist drivers with intersection recognition and have not exhibited an ability to address lag recognition and acceptance problems. Yet, up to 80% of crossing path crashes are related to selection of an insufficient lag (*1*). In addition, a Minnesota study of rural thru-STOP intersections for rural two-lane roadways found that only one-quarter of right angle crashes were caused by the driver on the minor street failing to stop because they did not recognize they were approaching an intersection (*2*). At the same set of intersections, 56% of the right angle crashes were related to selecting an unsafe lag while 17% were classified as other or unknown.

The concept of lag recognition being a key factor contributing to rural intersection safety appears to be a recent idea. As a result, there are relatively few devices in the traffic engineer's safety toolbox to assist drivers with lag recognition and they mainly consist of a few high cost geometric improvements and a variety of lower cost strategies that are considered to be experimental because they have not been widely used in rural applications. **Figure 1-1** illustrates the range of strategies currently available to address safety deficiencies associated with lag recognition problems, organized in order of the estimated cost to deploy (based on Minnesota conditions and typical implementation costs). The strategies include:

- The use of supplemental devices such as street light poles to mark the threshold between safe and unsafe lags
- Minor geometric improvements to reduce conflicts at intersection such as inside acceleration lanes, channelized median openings to eliminate certain maneuvers (sometimes referred to as a J-Turn), or revising a 4-legged intersection to create off-set T's
- Installing a traffic signal to assign right-of-way to the minor street

- Major geometric improvements such as roundabout or grade separated interchanges to eliminate to reduce crossing conflicts. (Refer to *Rural Expressway Intersection Synthesis of Practice and Crash Analysis* for a review of various alternatives [*3*].)

The use of these strategies may not be appropriate, warranted or effective in all situations. Also, the construction cost or right of way may prove to be prohibitive at some locations. All of this combined with a recommendation in AASHTO's Strategic Highway Safety Plan to investigate the use of technology to address rural intersection safety led to the on-going research to develop a cost-effective IDS system, including a new driver interface. The IDS system is intended to be a relatively low cost strategy (similar to the cost of a traffic signal), but at the same time is technologically advanced, using roadside sensors and computers to track vehicles on the major road approaches, computers to process the tracking data and measure available lags and then using the driver interface to provide minor road traffic with real-time information as to when it is unsafe to enter the intersection.

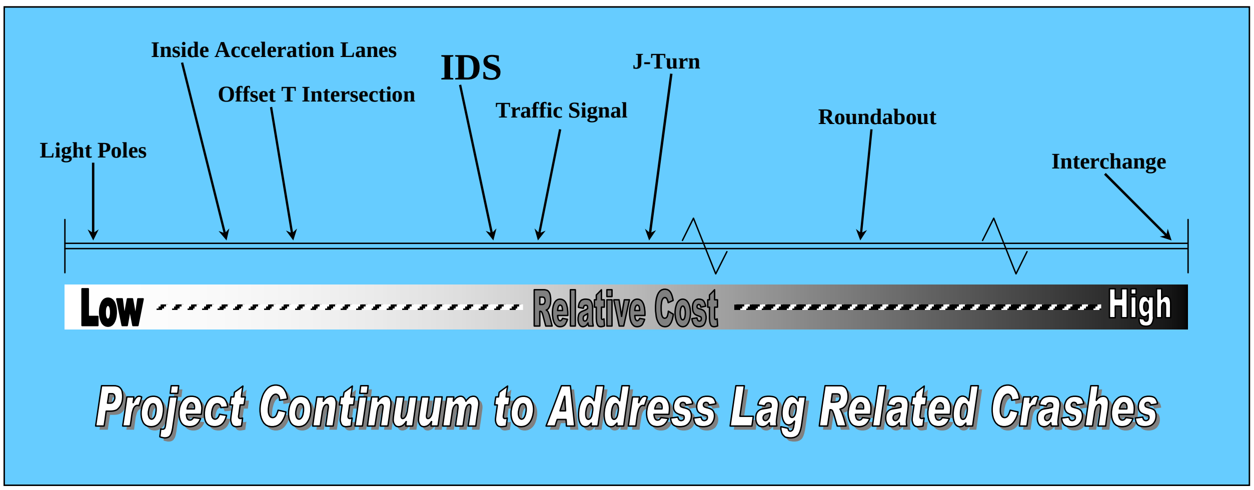

FIGURE 1-1
Lag Selection Related Safety Strategies

2. Crash Analysis Methods and Candidate Intersection Identification

A comprehensive method for intersection identification was developed using Minnesota's crash record system (see **Figure 2-1**).

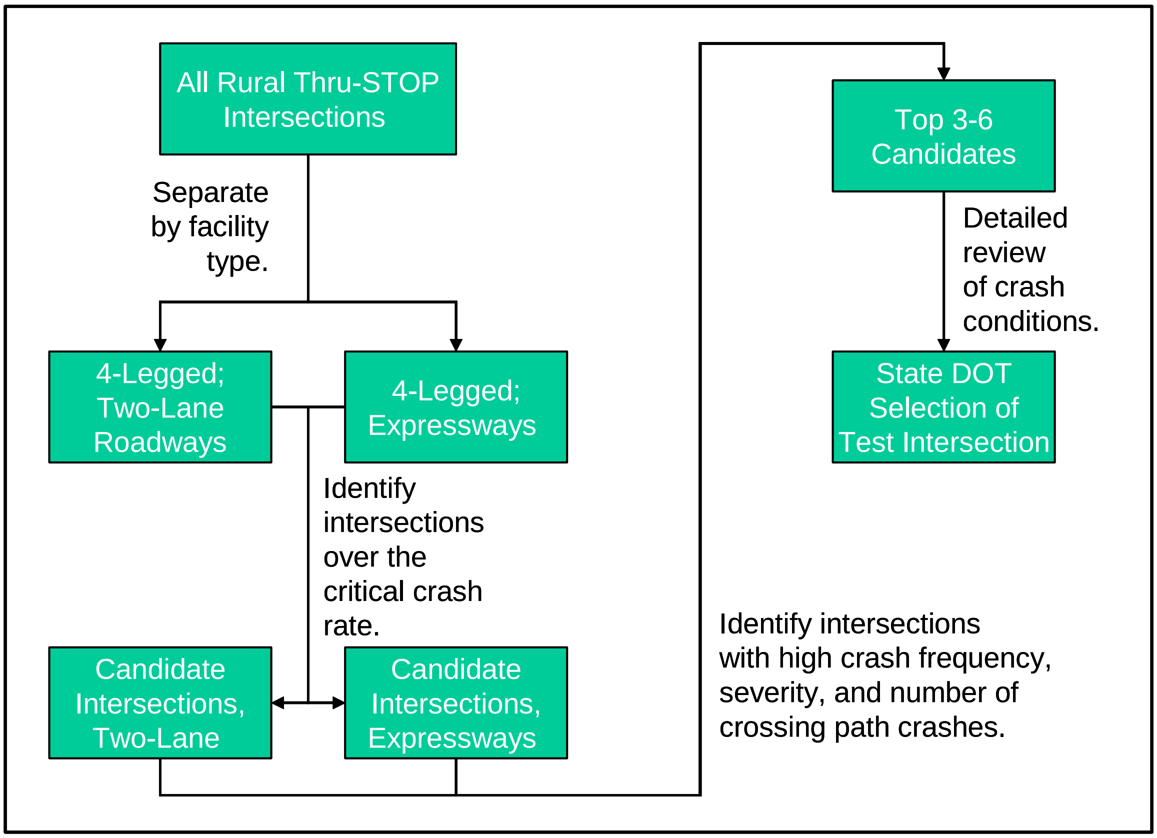

FIGURE 2-1
Preferred Crash Analysis Process

The method was applied to all rural, thru-STOP intersections in Minnesota, as this is the most frequent intersection situation in Minnesota. This intersection type is also the most likely where a driver will have to judge and select a lag at a rural intersection (i.e., stopped vehicle on the minor approach). The approach to identify the intersection selected for a potential field test of the technology used the three screens described in the following:

- **Critical Crash Rate –** The first screen was to identify the rural thru-STOP intersections that have a crash rate greater than the critical crash rate. The critical crash rate is a statistically significant rate higher than the statewide intersection crash rate. Therefore, any intersection with a crash rate equal to or above the critical crash rate can be identified as an intersection with a crash problem due to an existing safety deficiency.
- **Number and Severity of Correctable Crashes –** Once the intersections meeting the first criteria were identified, this second screen was performed to identify intersections where a relatively high number and percentage of crashes were potentially correctable by the

IDS technologies being developed. In Minnesota's crash record system, "right angle" crashes were the crash type most often related to poor lag selection. Therefore the ideal candidate intersections had a high number and percentage of right angle collisions and tended to have more severe crashes. This screen was used to identify the top three candidate intersections for the final screen.

- **Crash Conditions and At-Fault Driver Characteristics –** The IDS system is believed to have the greatest benefit for older drivers. Therefore, the at-fault driver age was reviewed to identify intersections where older drivers were over represented. Other aspects of the crashes that were reviewed include whether the crashes were typically a problem with intersection recognition or lag recognition and the crash location (near lanes or far lanes).

In California, application of the preferred process was not feasible due to the State DOT's current crash record system. The State has no database of intersection characteristics (i.e., rural versus urban, traffic control device, roadway type, etc.) that is linked to the crash records. Essentially, California is currently unable to automatically identify and query intersections (including crash records) based on physical characteristics and type of traffic control. Therefore, a modification of the approach was needed since it was impractical to manually search the entire State for all rural, thru-STOP intersections.

The screening process in California began with the California Department of Transportation (CALTRANS) providing crash records for rural thru-STOP intersections along four rural expressway corridors. The four corridors reviewed included:

- US 101 in Humboldt County (from reference point 80.260 to 83.920)
- US 101 in Ventura County (from reference point 40.891 to 41.471)
- State Route 99 in Merced County (from reference point 1.560 to 8.440)
- State Route 86 (spur) in Riverside County (from reference point R3.484 to R13.110)

CALTRANS provided three years of crash data (October 1, 2003 – September 30, 2006) for State Route (SR) 86S and five years of crash data (July 1, 2001 through June 30, 2006) for the US 101 corridors and the SR 99 corridor. Along these four corridors, CALTRANS provided crash summary reports for 23 intersections. From these 23 intersections, the crash summary statistics provided by CALTRANS identified two locations along SR 86S where there was a high crash frequency along with a high frequency of broadside crashes — the target crash type. However, unusual geometry and recent safety improvement projects (i.e., traffic signal installation) made it unnecessary to included this corridor in the detailed crash analysis. From the remaining locations, three locations stood out as having a combination of high frequency of total crashes and a high frequency of broadside crashes, and were included in the detailed analysis. After the detailed analysis began, one of the three intersections had to be eliminated because many of the broadside crashes were actually determined to be a left-turn head-on crash after the investigating officer's narrative was reviewed — the California crash records system does not distinguish between a right angle crash (involves one vehicle from both the major and minor roads) and a left-turn head-on crash (involves two vehicles on the major road, one of which is turning left). The two remaining intersections that best fit the study's criteria were:

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Despite the direct selection of the instrumented location, Chapter 3 still provides a review of the crash characteristics for all three final locations considered in the selection process.

3. Crash Record Review of Candidate Intersections

It was already known that the final three intersections considered for instrumentation had a relatively high frequency of crossing path crashes, but the crashes at each intersection were investigated further to identify specific information pertinent to the IDS system and also to learn of any unusual circumstances at the intersections. At the candidate intersections, the factors reviewed included at-fault driver age, crash severity, crash location, contributing factors, and the effects of weather. For all of these summaries, the focus is on the correctable crossing path crashes (see following section for definition), which are the types that have the greatest potential to be corrected by the IDS system.

3.1. Correctable Crash Types

The General Estimates System (GES) crash database is a national sample of police-reported crashes used in many safety studies. In the GES, five crossing path crash types have been identified (see **Figure 3-1**), they are:

- Left Turn Across Path – Opposite Direction (LTAP/OD),
- Left Turn Across Path – Lateral Direction (LTAP/LD),
- Left Turn Into Path – Merge (LTIP),
- Right Turn Into Path – Merge (RTIP), and
- Straight Crossing Path (SCP).

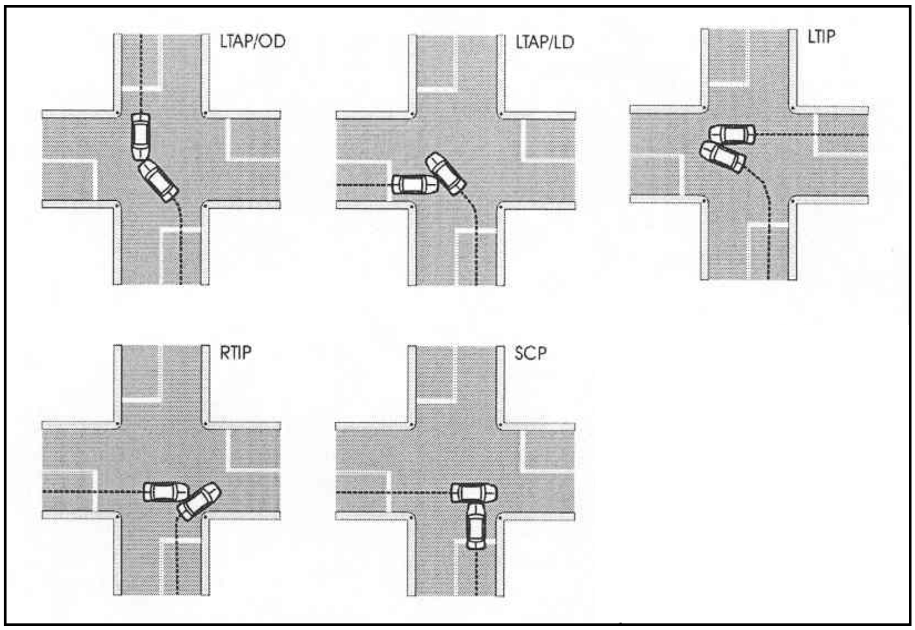


FIGURE 3-1
GES Crossing Path Crash Types

At this time, the IDS system under development is intended to address the crash types involving at least one vehicle from the major and minor street, which includes all five GES crash types except for LTAP/OD. This research has not focused on the LTAP/OD crash (referred to earlier as a left-turn head-on crash) type at unsignalized rural intersections because they are generally a relatively small problem at many locations. However, it is believed the system could be adapted to address LTAP/OD crashes if an intersection had a significant number of these crashes, such as at the one location that was eliminated from further study. For example, LTAP/OD crashes involving two vehicles from the minor street may be reduced if the device is designed to detect potential conflicts with vehicles from the opposing approach.

At the candidate intersections, the number and percent of correctable crashes is summarized in **Table 3-1**. Correctable crashes were identified using the collisions diagrams included in **Appendix A**. The crash data provided for the two intersections on US 101 was five years, 2002-2006. While the provided information for the location on US 395 was only three years of information, 2004-2006. For easier comparison, the number of crashes per year is also included in Table 3-1. As shown in **Table 3-1**, 25% and 38% of the crashes at the US 101 candidate intersections are potentially correctable. While the US 395 intersection had fewer crashes, all crashes were a crossing path crash. Looking at the number of correctable crashes per year, the experience at the three intersections was nearly identical.

The percentage of crossing path crashes at the two US 101 intersections is typically lower than seen at other states. However, the crash diagrams in Appendix A show many rear end crashes on US 101 (which is the uncontrolled approaches) and run-off the road crashes in the intersection area. Many of these crashes did not occur because of the intersection but were simply near the intersections. For example, the rear end crashes were often due to stopped or slow traffic in the road (corridor congestion) and not because of the intersection (vehicles slowing to turn). If these non-intersection related crashes were removed, the percentage of crossing path crashes would increase, generally bringing California closer to the experience in the other pooled fund states.

TABLE 3-1
Potential Correctable Crashes for IDS System at the Candidate Intersections

	US 101 & Ocean Drive (Ventura County)	**US 101 & La Conchita Road (Ventura County)**	**US 395 & Gill Station Coso Road (Inyo County)**
Total Crash Frequency [Total (per Year)] *	24 (4.8)	32 (6.4)	5 (1.7)
Number of Correctable Crashes *	9 (1.8)	8 (1.6)	5 (1.7)
Percent of Crashes that are Correctable *	38%	25%	100%

NOTE: Correctable crashes have been defined as SCP, LTAP/LD, LTIP, and RTIP.

* Crash Data provided for the US 101 corridor included 2002-2006. The crash data provided for US 395 was 2004-2006.

3.2. At-Fault Drivers

For the candidate intersections, officer reports were reviewed to identify the driver whose action most likely caused the accident, also known as the at-fault driver (see **Figure 3-2**). Which driver was determined to be the at-fault driver was made using the narrative recorded by the investigating officer. For the at-fault drivers, the age was determined to be an important piece of information and was recorded because the IDS system may have its greatest benefit in assisting older drivers in particular. Unfortunately, the age of the drivers involved in the crashes at US 101 and La Conchita Road had been removed from most of the officer reports due to data privacy issues. However, this information was provided for the remaining two locations.

From the *2005 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions* prepared by the California Highway Patrol, it is known that the age distribution of at-fault drivers in fatal and injury crashes is that 17.4% of drivers were under the age of 21, 68.8% of drivers were between the age of 21 and 64, 6.9% of drivers were over the age of 64, and the age was unknown for 6.9% of drivers. *Note: Age distributions in the* 2005 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions *were for fatal and injury crashes only while this study looked at all crossing path crashes at the candidate locations regardless of severity.*

At the intersection of US 101 and Ocean Drive, older drivers (age > 64-years) were determined to account for 56% of the at-fault drivers involved in the crossing path crashes. This is more than eight times greater than the statewide average of at-fault older drivers in fatal and injury crashes. At US 395 and Gill Station Coso Road, while the percentage of older drivers was above the statewide experience, it is considerably less than US 101 and Ocean Drive. As stated earlier, the driver information was removed from most of the officer reports at US 101 and La Conchita Road and prevented a similar analysis.

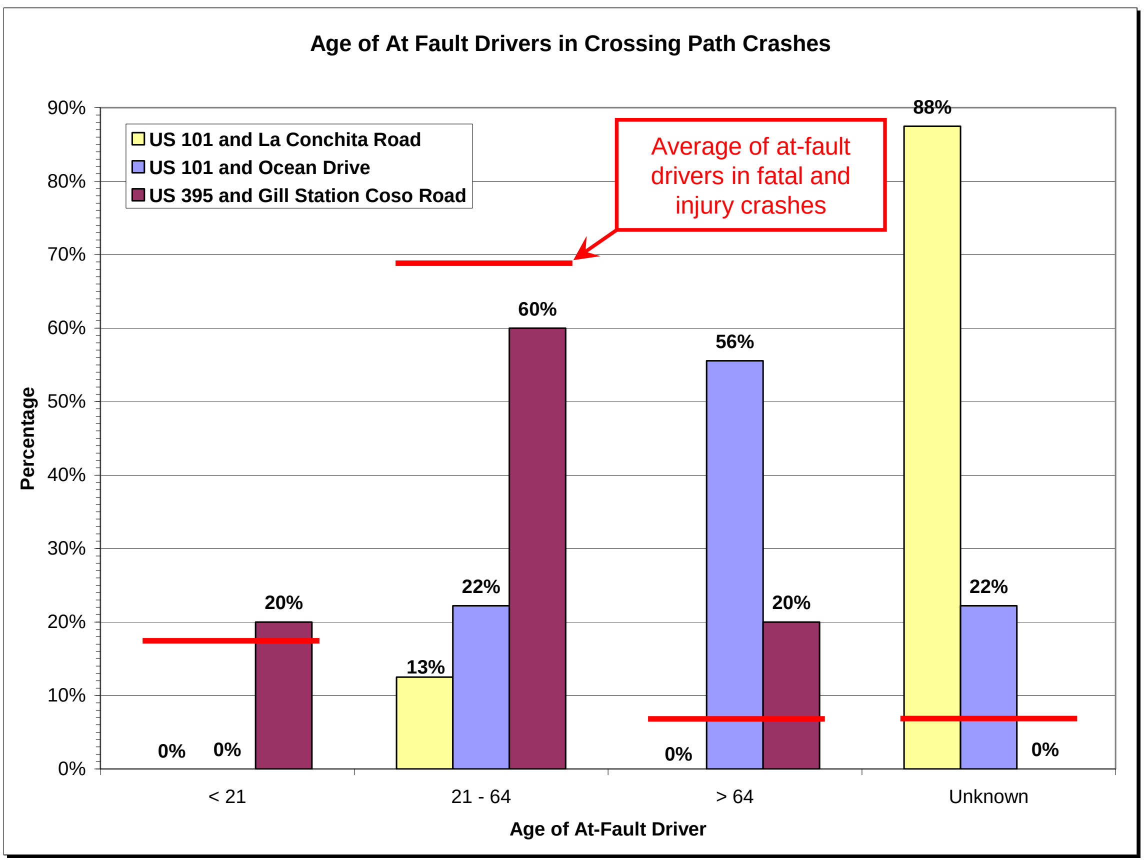


FIGURE 3-2
Age of At-Fault Drivers in Correctable Crash Types at the Candidate Intersections

3.3. Crash Severity

Another goal of the IDS system is to address the most serious intersections crashes, especially fatal crashes. Therefore, the most appropriate candidate intersection would have a high percentage of fatal and injury crashes. Of California's 2005 crashes, fatal crashes represented approximately 0.7% of all of crashes, with injury crashes at 37.3% and property damage (PD) crashes accounting for 62.0% of all crashes (Source: *2005 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions*). **Figure 3-3** shows that neither intersection on US 101 had a fatal crash during the study period; however, this is not unusual given that fatal crashes are a rare event in comparison to injury and PD crashes. Of the two US 101 intersections, the percentage of crossing path crashes that resulted in an injury at US 101 and La Conchita Road was approximately twice the rate for all crashes in the state. The crash severity at US 395 was unusually high, with 40% of crashes resulting in a fatality and the remaining involving an injury.

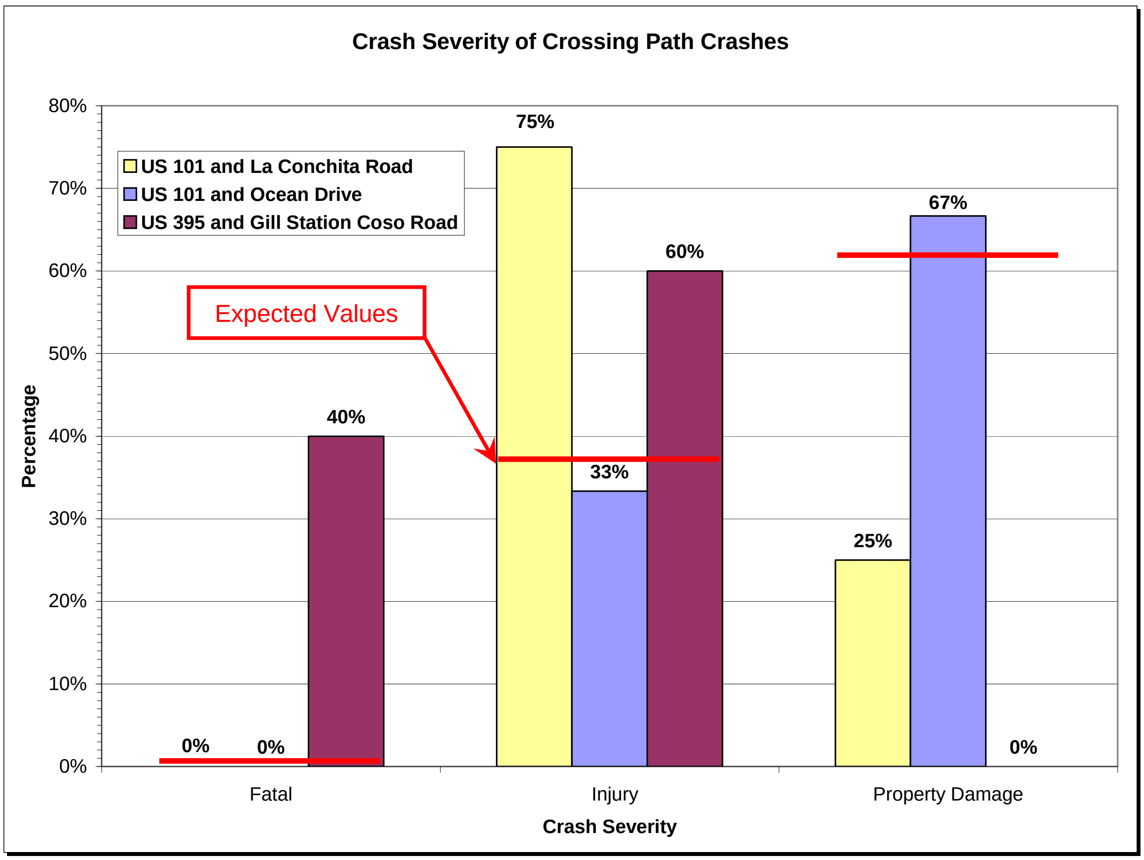


FIGURE 3-3
Crash Severity of Correctable Crash Types at the Candidate Intersections

3.4. Crash Location

From the initial review of Minnesota's crash records (*4*), it was observed that crossing path crashes at the candidate intersections were predominately on the far side of the intersection. [NOTE: For the divided expressway in Minnesota, a far-side crash occurs when the stopped vehicle safely negotiates the first two lanes it crosses, but is involved in a crash when leaving the median to either cross or merge into traffic in the second set of lanes.] The primary cause of the high number of far-side crashes was not evident from review of the crash records. However, it was speculated that drivers used a one-step process for crossing rather than a two-step process. When a driver enters the median, rather than stopping to reevaluate whether the lag is still safe (a two-step process), it is believed that drivers simply proceeded into the far lanes without stopping (a one-step process). At the selected intersection in Minnesota (U.S. 52 and Goodhue County 9), vehicle detection equipment has already been installed along with video cameras. The information recorded at the intersection will be used to quantify how drivers typically cross this and similar intersections. Similar to what was observed in the Minnesota crash data; all crashes captured by the vehicle surveillance system at the Minnesota test intersection have been far-side crashes. The one crash recorded during the deployment at the test intersection in Wisconsin was a near-side crash; however, that intersection was unique in that crossing path crashes were nearly spilt equally between far-side and near-side.

For the pooled fund study to date, rural expressway intersections in Nevada, North Carolina, Wisconsin, and Iowa have been reviewed. For the candidate intersections in North Carolina, Wisconsin and Iowa, the pattern was similar to what was observed in Minnesota with a majority of crossing path crashes occurring in the far-side lanes. However, Nevada differed in that a majority of crossing path crashes were near-side crashes.

At the US 101 locations (see **Figure 3-4**), nearly all correctable crossing path crashes were near - side crashes. This pattern is generally opposite of what was found in the other states that selected to study rural expressways. This may be a result of the T-intersection design or the left-turn median acceleration lanes which help prevent far side crashes. In contrast, all crossing path crashes at US 395 and Gill Station Coso Road were farside crashes.

3.5. Driver Recognition

Another important crash characteristic is whether the at-fault driver failed to recognize the intersection (i.e., ran-the-STOP) or failed to select a safe lag (i.e., stopped, pulled out). Since the IDS device is primarily intended to help drivers with selecting safe lags, crashes where the driver ran-the-STOP may not be correctable by the proposed IDS system. To classify the crashes as either intersection recognition or lag recognition, the narrative recorded by the investigating officer was used. In many instances, the investigating officer reported whether or not the at-fault driver stopped or failed to stop. However, some crash reports did not include this information in the narrative. For these crashes, additional information may have been available to determine the contributing factor. For example, the investigating officer may have reported that the driver was turning onto the highway from the side street. Even though the officer did not comment if the driver stopped, the driver’s decision to turn at the intersection is a strong indication that they were aware of the intersection but was unable to select a safe lag. This scenario would have been classified as a lag recognition crash.

As shown in **Figure 3-5**, 88% of the crossing path crashes at US 101 and La Conchita Road were lag recognition and all crossing path crashes at US 101 and Ocean Driver as well as US 395 and Gill Station Coso Road were lag recognition crashes. This strongly suggests that a high percentage of these crossing path crashes could have been prevented if the at-fault drivers had assistance in identifying, judging and selecting a safe lag.

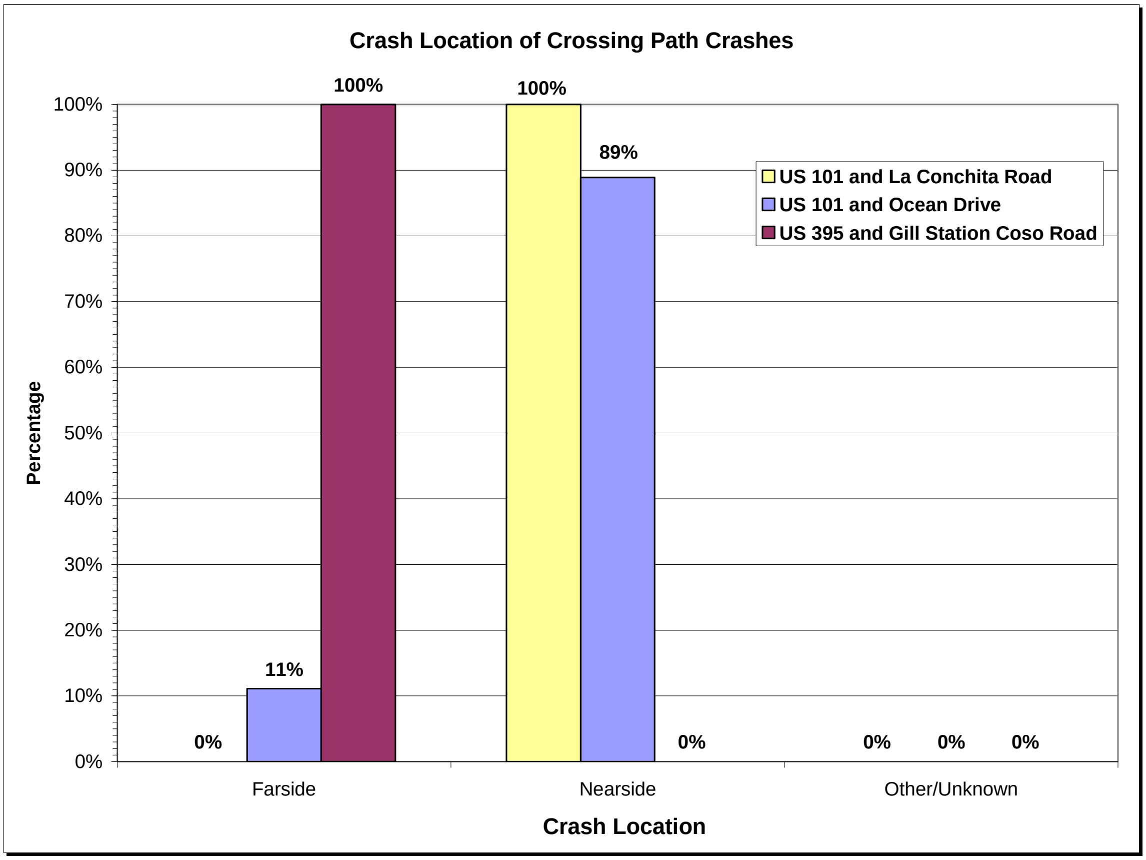


FIGURE 3-4
Crash Location of Correctable Crash Types at the Candidate Intersections

3.6. Effect of Weather, Road Condition, and Light Condition

The final factors reviewed for the crossing path crashes at each candidate intersection were the weather, road, and light conditions. If the crashes tended to occur during adverse weather conditions (i.e., snow, rain, dark), then deployment of a new technology may have a limited benefit unless it can be coordinated with a local RWIS station.

The weather condition at the time of the crashes (see **Table 3-2**) was clear or cloudy for all crashes. This indicates that weather was not a significant contributing factor in the crossing path crashes that occurred at the candidate intersections.

The road surface condition (see **Table 3-3)** was reported as dry except for one crash at the intersection of US 1010 & La Conchita Road. This single crossing path crash occurred on a wet pavement. This is indicates that adverse weather was not a causal factor in crossing path crashes.

The percentage of crossing path crashes reported during daylight conditions at the candidate intersections was at or above 75% (see **Table 3-4**), indicating dark or low-light driving conditions were not a substantial factor in causing crossing path crashes.

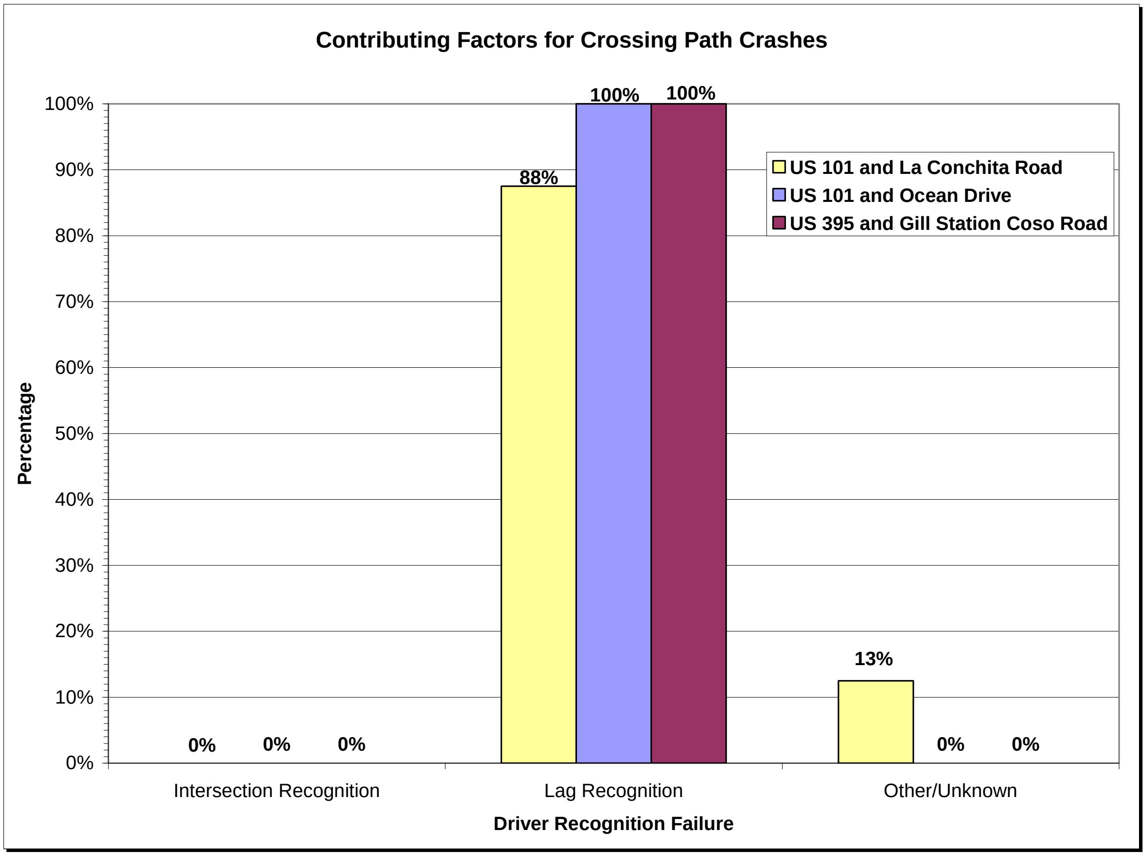


FIGURE 3-5
Contributing Factors of Correctable Crash Types at the Candidate Intersections

TABLE 3-2
Weather Condition for Correctable Crash Types at the Candidate Intersections

	US 101 & Ocean Drive (Ventura County)	**US 101 & La Conchita Road (Ventura County)**	**US 395 & Gill Station Coso Road (Inyo County)**
Clear or Cloudy	100%	100%	100%
Rain	0%	0%	0%
Snow or Sleet	0%	0%	0%

TABLE 3-3
Roadway Surface Condition for Correctable Crash Types at the Candidate Intersections

	US 101 & Ocean Drive (Ventura County)	US 101 & La Conchita Road (Ventura County)	US 395 & Gill Station Coso Road (Inyo County)
Dry	100%	88%	100%
Wet	0%	12%	0%
Snow or Ice	0%	0%	0%

TABLE 3-4
Light Condition for Correctable Crash Types at the Candidate Intersections

	US 101 & Ocean Drive (Ventura County)	US 101 & La Conchita Road (Ventura County)	US 395 & Gill Station Coso Road (Inyo County)
Daylight	100%	75%	80%
Dawn or Dusk	0%	0%	0%
Dark	0%	25%	20%

4. Intersection Field Conditions

Because initially only two candidate locations were identified in California, the research team did not conduct field reviews of the locations. Instead, the CALTRANS provided site photos for the two intersections and a conference call including the research team and the CALTRANS was held to discuss any potential factors that may affect the locations' feasibility for use in this study.

Following is a brief description of each of the intersections. For each intersection, crash diagrams are included in **Appendix A** and aerial photos are in **Appendix B**.

4.1. US 101 & Ocean Drive (Ventura County)

The intersection of US 101 and Ocean Drive is a T-intersection located in Ventura County, north of the Los Angeles area. US 101 is a rural expressway with the through approaches, generally running northwest-southeast. This area of US 101 is immediately past where the design transitions from an access controlled freeway to rural expressway. As such, the volumes in the corridor are high, approximately 67,000 vehicles per day. Ocean Drive is the stop controlled approach and provides local access to a small, isolated commercial and residential area between US 101 and the ocean.

In photos provided by the CALTRANS, it was discovered that the Ocean Drive approach (**Figure 4-1**) does include a single approach lane with one stop sign set off far to the right. However, the lack of intersection recognition crashes do not point to the placement of the stop sign being a problem. Also visible in **Figure 4-1** is the intersection lighting at the intersection.

Ocean Drive is a low-speed roadway, serving local traffic and providing parking for local business (see **Figure 4-2**). In fact, immediately east of the intersection is a parking lot for the Cliff House Inn.

The collision diagram in **Appendix A** reveals that eight of the nine correctable crossing path collisions involved a driver on the Ocean Drive approach turning left. Furthermore, all eight crashes involved a vehicle on US 101 approaching from the west (left).

FIGURE 4-1
Ocean Drive Approach

FIGURE 4-2
Parking to the West (left photo) and East (right photo) of the Intersection

4.2. US 101 and La Conchita Road (Ventura County)

The intersection of US 101 and La Conchita road is a T-intersection located approximately 0.5 mile from the US 101 and Ocean Drive. (For a description of US 101, refer to the previous section.) La Conchita Road is the stop controlled approach at the intersection and primarily provides access to the community of La Conchita (2000 Census Population less than 500) and rural areas in the hills to the north and west of La Conchita.

The La Conchita approach is shown in **Figure 4-2**. This photo also shows that a railroad track parallels US 101 and separates the Town of La Conchita from the highway. The at-grade railroad crossing include a gate with flashers. The photos from the CALTRANS also show that this intersection includes street lighting.

FIGURE 4-3
La Conchita Road Approach

The collision diagram (**Appendix A**) shows that seven of the eight correctable crossing path crashes involved a vehicle from La Conchita turning left into the path of a vehicle approach form the left. This is the same pattern observed at US 101 and Ocean Drive.

4.3. US 395 and Gill Station Coso Road (Inyo County)

US 395 and Gill Station Coso Road is a thru-STOP intersection located on the east side of central California. The land on the west side of US 395 is vacant while a few buildings are located to the east of the intersection, including a small rest stop.

One unique aspect of this intersection is the wide median, which provides approximately 150 feet of storage in the median. Because of the extra storage space, STOP signs (instead of YIELD signs) have been placed at the each end of the median. Other safety countermeasures visible in Figure 4-4 include intersection lighting, warning signs mounted under STOP sign to remind drivers that traffic from left/right does not stop, and LED flashers around the face of STOP signs (powered by solar panels). Also visible in the aerial image (Appendix B) is an inside acceleration lane for vehicles turning left onto southbound US 395 and a free right for vehicles turning right onto northbound US 395.

FIGURE 4-4
View of Median from East Approach of Gill Station Coso Road

The US 395 alignment in the vicinity of the intersection is straight and nearly flat (see **Figure 4-5**), which means drivers on Gill Station Coso Road or in the median have no alignment related obstacles to identifying approaching vehicles and judging lags. While the US 395 alignment doesn’t create any barriers for entering traffic, it was observed that the placement of a DO NOT ENTER and WRONG WAY sign does create a large blind spot. The specific sign combination is in the driver’s sight triangle when looking south from the median (see **Figure 4.6**). Interestingly, all five crashes at the intersection included vehicles making this crossing movement. However, the location of the sign was not specifically listed as a cause in any officer report.

FIGURE 4-5
View of US 395 Approach Alignment for Northbound (left photo) and Southbound (right photo) Traffic

FIGURE 4-6
Sight Obstruction While Looking South from the Median

5. Summary and Intersection Recommendation

A summary of the pertinent crash statistics has been summarized in **Table 5-1** for the three candidate intersections. Following is a set of general observations from the analysis and review of the California candidate intersections.

- CALTRANS has applied various safety countermeasures at these intersections. Some countermeasures, such as street lights and LED flashers on face of STOP sign, would primarily address crossing path crashes where driver failed to recognize they were approaching an intersection. These appeared to be successful since at preventing intersection recognition crashes.
- At US 395 and Gill Station Coso Road, inside median acceleration and signing warning drivers that vehicle approaching from left/right do not stop would be intended to address lag recognition crashes. However, all five crashes at the intersection were a crossing path crash where the driver failed to recognize or properly judge approaching traffic.
- The crash characteristics for the subset of high crash frequency intersections examined are very similar to the data for comparable intersections in Minnesota. The distribution of crash types is skewed to crossing path crashes, lag related, often more severe than expected, and typically not caused by weather and/or light conditions.

5.1. Intersection Selected for Deployment

Of the original 23 locations selected by CALTRANS, the final two intersections considered for instrumentation were on US 101. Because of right-of-way constraints, the mobile vehicle surveillance equipment could not be deployed along US 101 and CALTRANS had to identify a new location for instrumentation. Through a process of working directly with the Districts to identify a location with a know safety issue, US 395 and Gill Station Coso Road was recommended for further study. Comparison of the crash data for the three locations revealed that the US 395 location had a similar annual number of crossing path crashes, the crashes tend to be more severe, and all crossing path crashes were on the far side (similar to patterns seen in other participating states) and related to lag recognition.

Additionally, the candidate locations on US 101 were T-intersections and had very high volumes for an expressway design (the two locations were located just after US 101 transitions from a freeway to an expressway). These conditions are unlike any intersections where driver behavior was monitored as part of this project. Whereas the geometry and volumes of US 395 was more consistent with intersections studied in other states.

Even though the intersection has an wide median that allows for STOP signs to be used in the median (instead of YIELD signs), this has a similar design to the Wisconsin location and may provide for better comparison of wide versus narrow medians once all driver behavior data is collected and analyzed.

TABLE 5-1
California Intersection Summary

Performance Measure	US 101 & Ocean Drive (Ventura County)	US 101 & La Conchita Road (Ventura County)	US 395 & Gill Station Coso Road (Inyo County)
Crash Frequency	24	32	5
Crash Severity			
Fatal	0 (0%)	0 (0%)	2 (40%)
Injury	10 (42%)	14 (44%)	3 (60%)
PDO	14 (58%)	18 (56%)	0 (0%)
Daily Entering ADT	67,000	67,000	6,150
Crash Rate	0.2	0.3	0.4
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.5	0.5	0.8
Correctable Crash Type	9 (38%)	8 (25%)	5 (100%)
Crash Severity			
Fatal	0 (0%)	0 (0%)	2 (40%)
Injury	3 (33%)	6 (75%)	3 (60%)
PDO	6 (67%)	2 (25%)	0 (0%)
At-Fault Driver			
< 21	0 (0%)	0 (0%)	1 (20%)
21 – 64	2 (22%)	1 (12%)	3 (60%)
> 64	5 (56%)	0 (0%)	1 (20%)
Unknown	2 (22%)	7 (88%)	0 (0%)
Crash Location			
Farside	1 (11%)	0 (0%)	5 (100%)
Nearside	8 (89%)	8 (100%)	0 (0%)
Unknown	0 (0%)	0 (0%)	0 (0%)
Contributing Factors			
Int Recg	0 (0%)	0 (0%)	0 (0%)
Lag Recg	9 (100%)	7 (88%)	5 (100%)
Other	0 (0%)	1 (12%)	0 (0%)

References

1. W.J Najm, J.A. Koopmann and D.L. Smith. "Analysis of Crossing Path Crash Countermeasure Systems." Proceedings of the *17th International Technical Conference on the Enhanced Safety of Vehicles*, Amsterdam, The Netherlands. June 2001.
2. K.A. Harder, J. Bloomfield, and B.J. Chihak. *Crashes at Controlled Rural Intersection*. Report MN/RC-2003-15. (St. Paul: Local Road Research Board, Minnesota Department of Transportation. July 2003.)
3. T. Maze, N. Hawkins, and G. Burchett. *Rural Expressway Synthesis of Practice and Crash Analysis*. CTRE Project 03-157. (Ames: Iowa Department of Transportation. October 2004.)
4. H. Preston, R. Storm, M. Donath, and C. Shankwitz. *Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support*. Report MN/RC-2004-31. (St. Paul: Minnesota Department of Transportation. May 2004.)

Appendix A

Intersection Crash Diagrams

Collision Diagram

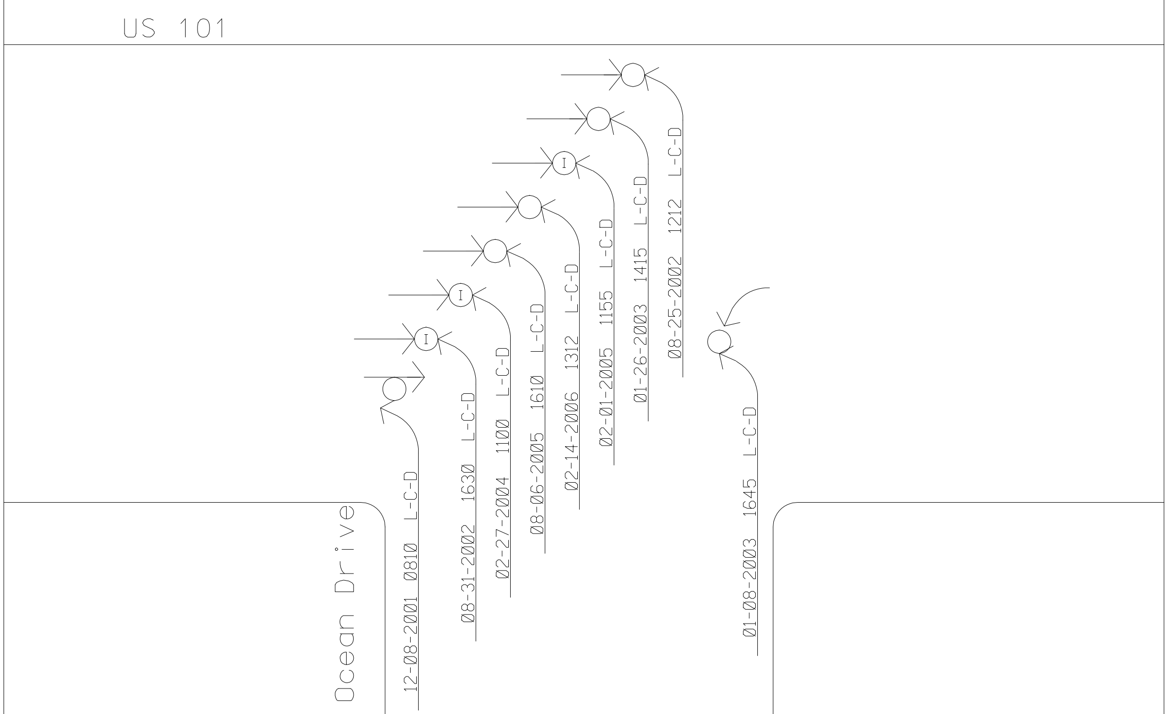
Location: US 101 & Ocean Drive (Ventura County) 1 of 2

Time Period: 07/01/2001 - 06/30/2006

Prepared By: rjs Date: 12-14-2007

No. of Accidents	
Fatal=	0
Injury Total=	10
Property Damage=	14
Total Accidents=	24

Indicate North



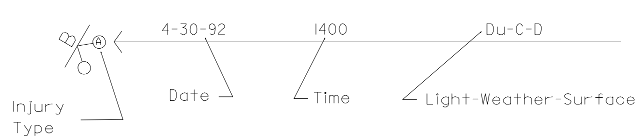
Motor Vehicle Ahead
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Acc.
Injury Acc.
* Location/Details Unclear
Property Damage Acc.
Rear End Property Damage
Right Angle Injury

Light:
L= Daylight
DN= Dawn
Du= Dusk
D= Dark
X= Unknown

Weather:
C= Clear or Cloudy
R= Rain
S= Snow or Sleet
X= Other or Unknown

Surface:
D= Dry
W= Wet
S= Snow or Ice
X= Other or Unknown

Example of Bicycle/Motor Vehicle Accident:



Collision Diagram

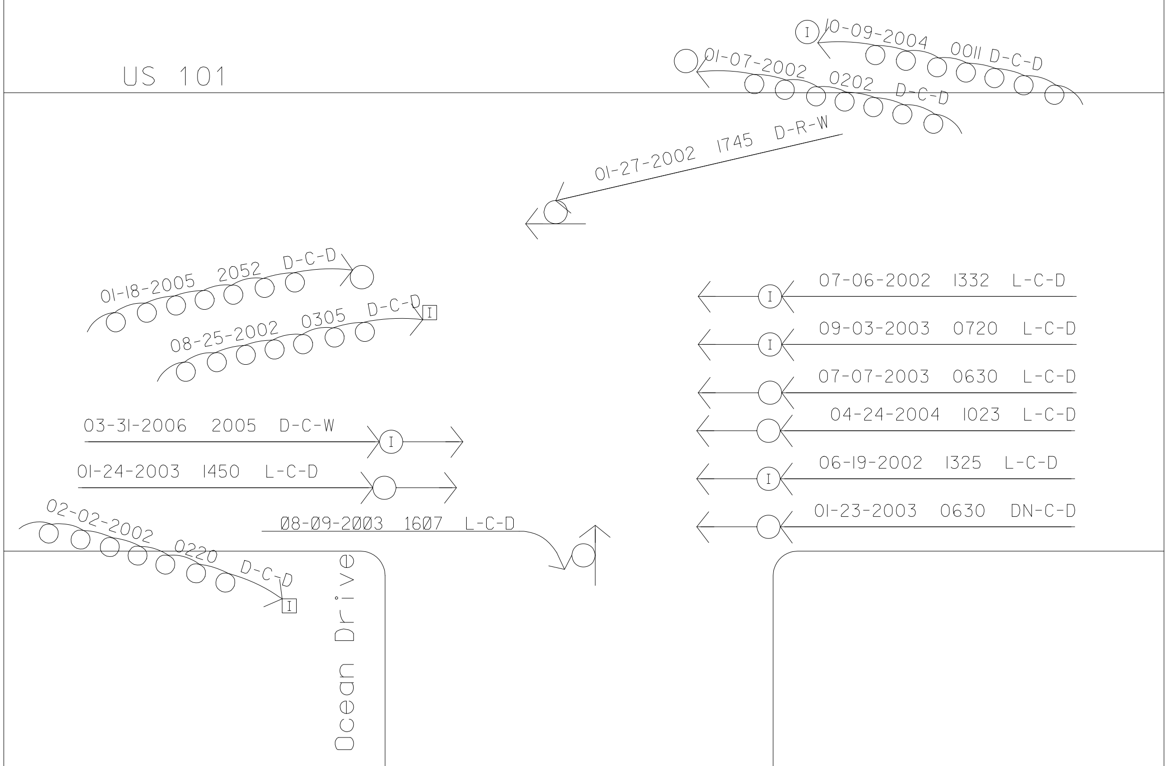
Location: US 101 & Ocean Drive (Ventura County) 2 of 2

Time Period: 07/01/2001 - 06/30/2006

Prepared By: rjs Date: 12-14-2007

No. of Accidents
Fatal= 0
Injury Total= 10
Property Damage= 14
Total Accidents= 24

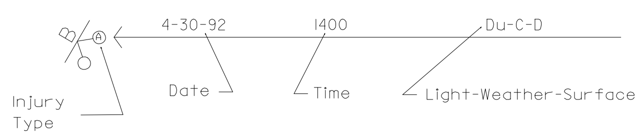
Indicate North



Motor Vehicle Ahead
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Acc.
Injury Acc.
* Location/Details Unclear
Property Damage Acc.
Rear End Property Damage
Right Angle Injury

Light:	Weather:	Surface:
L= Daylight	C= Clear or Cloudy	D= Dry
DN= Dawn	R= Rain	W= Wet
Du= Dusk	S= Snow or Sleet	S= Snow or Ice
D= Dark	X= Other or Unknown	X= Other or Unknown
X= Unknown		

Example of Bicycle/Motor Vehicle Accident:



Collision Diagram

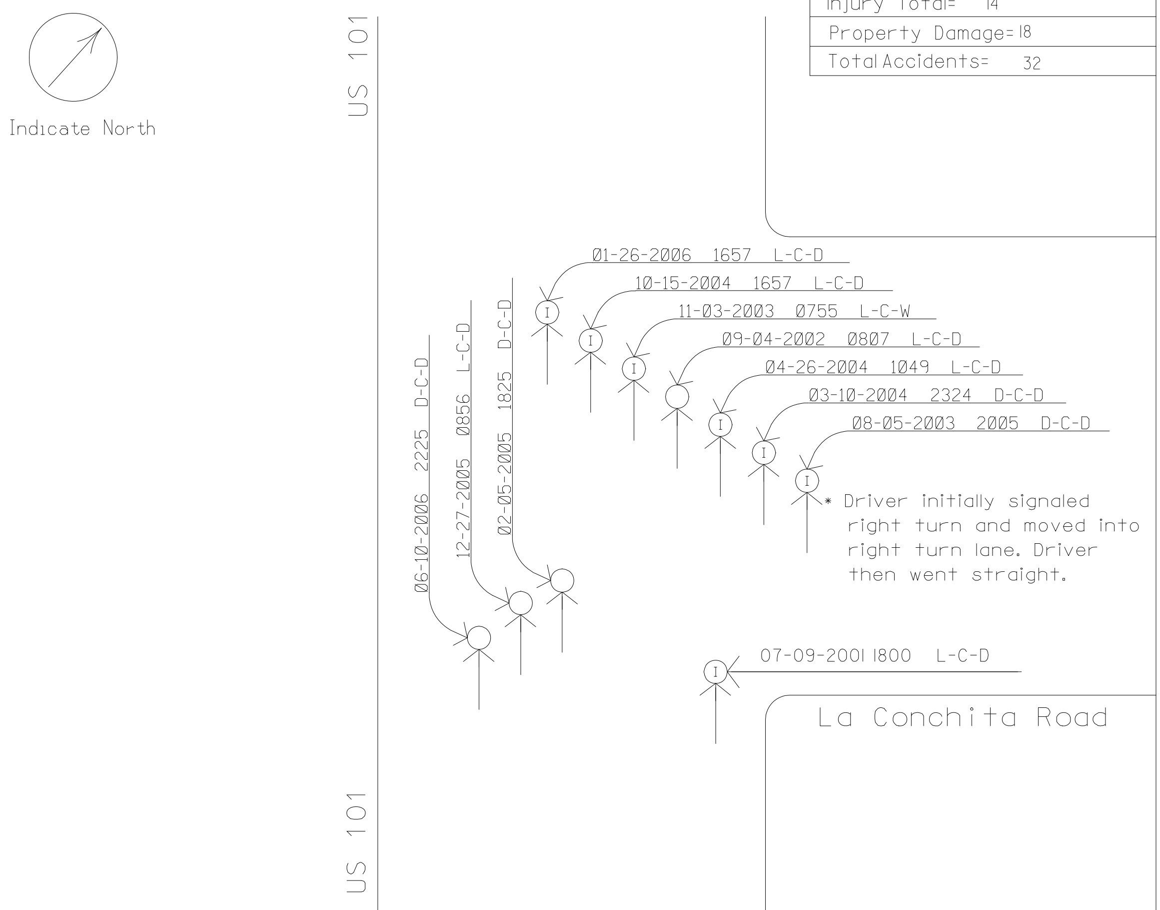
Location: US 101 & La Conchita Road (Ventura County) 1 of 3

Time Period: 07/01/2001 - 06/30/2006

Prepared By: rjs Date: 12-14-2007

No. of Accidents

Fatal=	0
Injury Total=	14
Property Damage=	18
Total Accidents=	32



	Light:	Weather:	Surface:
Motor Vehicle Ahead	L= Daylight	C= Clear or Cloudy	D= Dry
Motor Vehicle Backing Up	DN= Dawn	R= Rain	W= Wet
Motor Vehicle Out of Control	Du= Dusk	S= Snow or Sleet	S= Snow or Ice
Pedestrian	D= Dark	X= Other or Unknown	X= Other or Unknown
Bicycle/Moped	X= Unknown		
Motorcycle			
Fixed Object			
Fatal Acc.			
Injury Acc.			

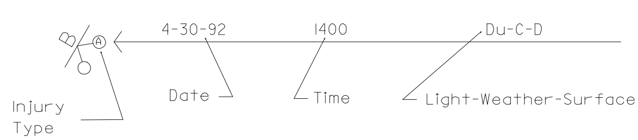
* Location/Details Unclear

○ Property Damage Acc.

Rear End Property Damage

Right Angle Injury

Example of Bicycle/Motor Vehicle Accident:



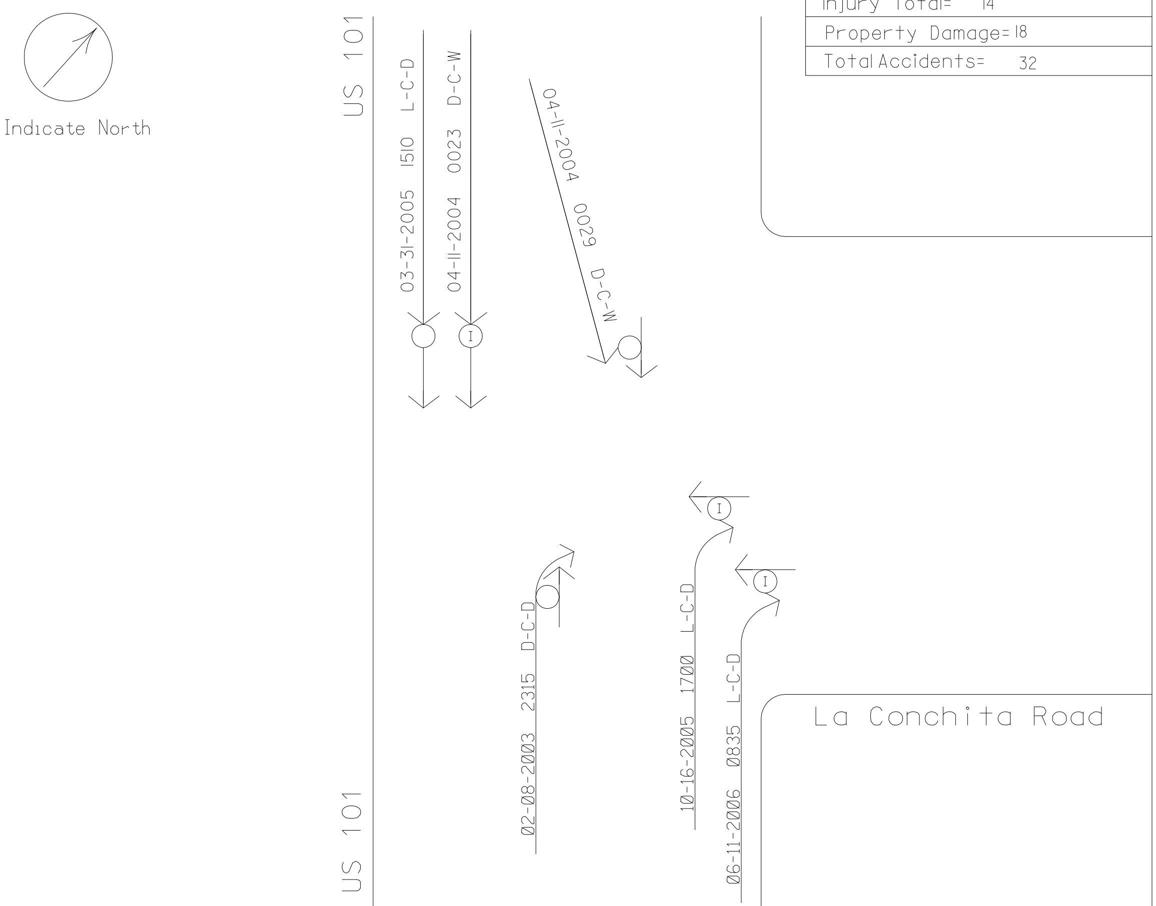
Collision Diagram

Location: US 101 & La Conchita Road (Ventura County) 2 of 3

Time Period: 07/01/2001 - 06/30/2006

Prepared By: rjs Date: 12-14-2007

No. of Accidents	
Fatal=	0
Injury Total=	14
Property Damage=	18
Total Accidents=	32



Motor Vehicle Ahead
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Acc.
Injury Acc.
* Location/Details Unclear
Property Damage Acc.
Rear End Property Damage
Right Angle Injury

Light:	Weather:	Surface:
L= Daylight	C= Clear or Cloudy	D= Dry
DN= Dawn	R= Rain	W= Wet
Du= Dusk	S= Snow or Sleet	S= Snow or Ice
D= Dark	X= Other or Unknown	X= Other or Unknown
X= Unknown		

Example of Bicycle/Motor Vehicle Accident:

4-30-92 1400 Du-C-D

Injury Type — Date — Time — Light-Weather-Surface

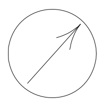
Collision Diagram

Location: US 101 & La Conchita Road (Ventura County) 3 of 3

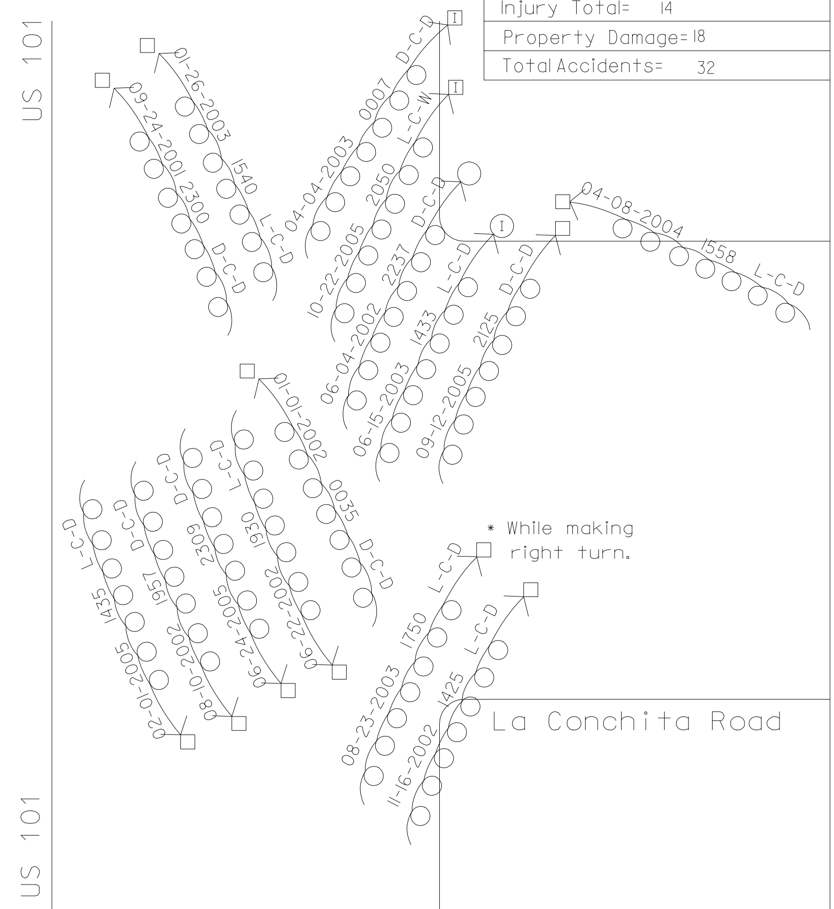
Time Period: 07/01/2001 - 06/30/2006

Prepared By: rjs Date: 12-14-2007

No. of Accidents	
Fatal=	0
Injury Total=	14
Property Damage=	18
Total Accidents=	32



Indicate North



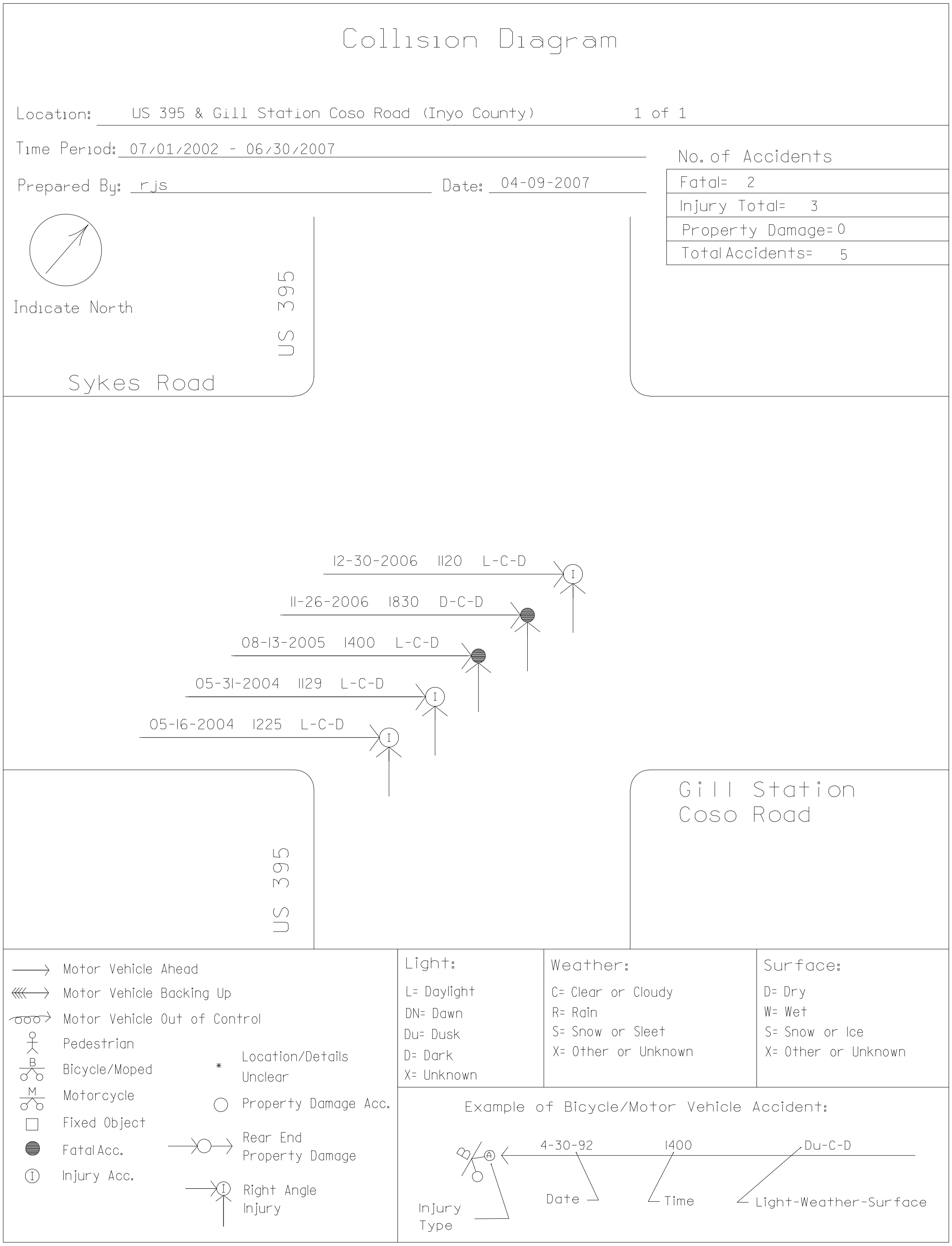
- Motor Vehicle Ahead
- Motor Vehicle Backing Up
- Motor Vehicle Out of Control
- Pedestrian
- Bicycle/Moped
- Motorcycle
- Fixed Object
- Fatal Acc.
- Injury Acc.
- * Location/Details Unclear
- Property Damage Acc.
- Rear End Property Damage
- Right Angle Injury

Light:	Weather:	Surface:
L= Daylight	C= Clear or Cloudy	D= Dry
DN= Dawn	R= Rain	W= Wet
Du= Dusk	S= Snow or Sleet	S= Snow or Ice
D= Dark	X= Other or Unknown	X= Other or Unknown
X= Unknown		

Example of Bicycle/Motor Vehicle Accident:

4-30-92 1400 Du-C-D

Injury Type — Date — Time — Light-Weather-Surface


Collision Diagram
Location: US 395 & Gill Station Coso Road (Inyo County) 1 of 1
Time Period: 07/01/2002 - 06/30/2007
Prepared By: rjs
Date: 04-09-2007
No. of Accidents
Fatal= 2
Injury Total= 3
Property Damage= 0
Total Accidents= 5
Indicate North
US 395
Sykes Road
12-30-2006 1120 L-C-D
11-26-2006 1830 D-C-D
08-13-2005 1400 L-C-D
05-31-2004 1129 L-C-D
05-16-2004 1225 L-C-D
US 395
Gill Station Coso Road
Motor Vehicle Ahead
Motor Vehicle Backing Up
Motor Vehicle Out of Control
Pedestrian
Bicycle/Moped
Motorcycle
Fixed Object
Fatal Acc.
Injury Acc.
Location/Details Unclear
Property Damage Acc.
Rear End Property Damage
Right Angle Injury
Light:
L= Daylight
DN= Dawn
Du= Dusk
D= Dark
X= Unknown
Weather:
C= Clear or Cloudy
R= Rain
S= Snow or Sleet
X= Other or Unknown
Surface:
D= Dry
W= Wet
S= Snow or Ice
X= Other or Unknown
Example of Bicycle/Motor Vehicle Accident:
4-30-92
1400
Du-C-D
Injury Type
Date
Time
Light-Weather-Surface

Appendix B

Aerial Photographs

FIGURE B-1

Aerial Photo of US 101 & Ocean Drive (Ventura County)

Source: The image has been modified from the original. The base map is from Google Earth Pro, but the data are from CH2M HILL.

FIGURE B-2
Aerial Photo of US 101 & La Conchita Road (Ventura County)

Source: The image has been modified from the original. The base map is from Google Earth Pro, but the data are from CH2M HILL.

FIGURE B-3
Aerial Photo of US 395 & Gill Station Coso Road (Inyo County)

Source: The image has been modified from the original. The base map is from Google Earth Pro, but the data are from CH2M HILL.