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

Report #6 in the Series: Toward a Multi-State Consensus on
Rural Intersection Decision Support

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Rural Intersection Decision Support

Final Report

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

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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 system is under development. 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
- 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 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.

Thus far in the states where the crash analysis is completed, the states where the focus was on rural, four-lane expressways (i.e., divided roadways) were Iowa, Minnesota, North Carolina and Wisconsin. While the states with a focus on two-lane highways (i.e., undivided) include Georgia, Michigan and New Hampshire.

Review of New Hampshire's Intersections

This report documents the initial phase of the pooled fund study for the State of New Hampshire. The crash analysis focused on thru-STOP intersections of two-lane U.S. or State routes throughout rural New Hampshire.

Based on an analysis of these intersections from across the state, locations with nine or more crashes between January 1, 2003 and December 31, 2005 were selected for further review. This resulted in a list of 20 intersections as candidates for further study, only four of which did not have a crash rate equal to or greater than the critical crash rate. Furthermore, several intersections were eliminated because of geometry, traffic control, and recent or planned improvements, which made the sites undesirable for this specific research topic. The three remaining intersections that best fit the study's criteria were:

1. NH 101 & NH 123 in Hillsborough County
2. NH 28 & NH 171 in Carroll County
3. NH 107 & NH 150 in Rockingham County

A field visit revealed that the New Hampshire Department of Transportation had already deployed safety countermeasures at these intersections, specifically intersection lighting, overhead red-yellow flashers, enhanced junction signing, turn lanes, two stop signs on an approach, and STOP AHEAD signs. However, these strategies would be most effective at addressing crashes in which the driver fails to recognize that he/she is approaching the intersection and thus runs the STOP sign. Neither countermeasure provides the driver with assistance in recognition and selection of safe lags in the stream of cross-traffic.

Examination of the crash data indicated that these strategies did prove effective at reducing run-the-STOP crashes since there were few of these crash types. However, the large numbers of crossing path crashes at the three candidate intersections were predominately associated with a driver's poor lag identification and selection.

Using the crash factors of at-fault driver age, crash severity, contributing factors associated with the driver, along with several other factors, the intersection selected as the overall best candidate for test deployment of the IDS vehicle surveillance system was NH 101 and NH 123. This intersection has one of the worst crash experiences, including the highest crash rate, the highest number and percentage of crashes that were classified as a crossing path crash, the highest number and percentage of injury crashes, and a high percentage of lag recognition crashes.

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 system is under development. 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:

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This report documents the initial phase of the pool fund study for the State of New Hampshire. Following is a description of the crash analysis performed for New Hampshire 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 [4].)

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 Intersection Decision Support (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.

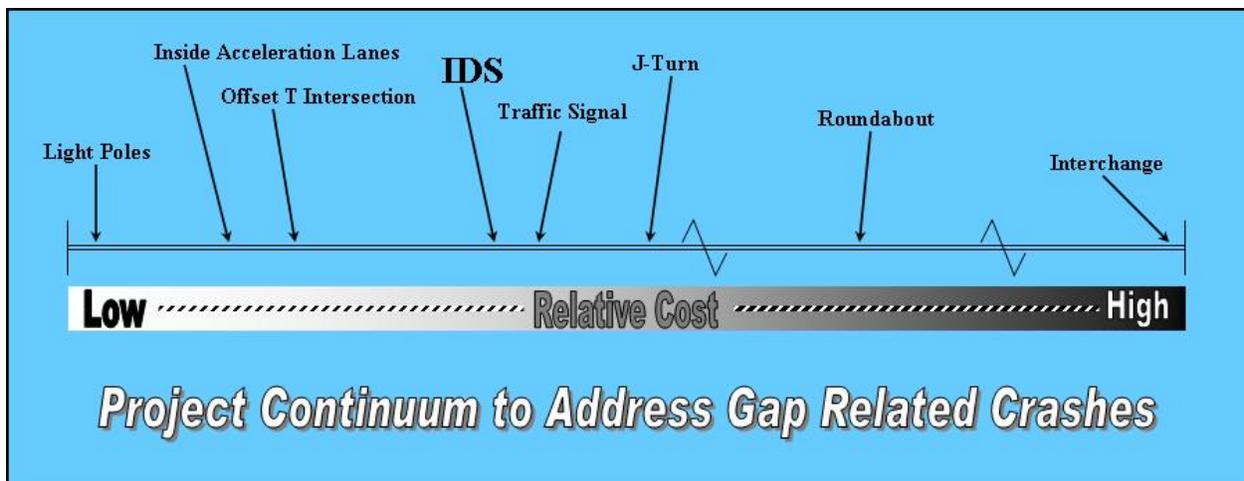


FIGURE 1-1
Lag Selection Related Safety Strategies

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**).

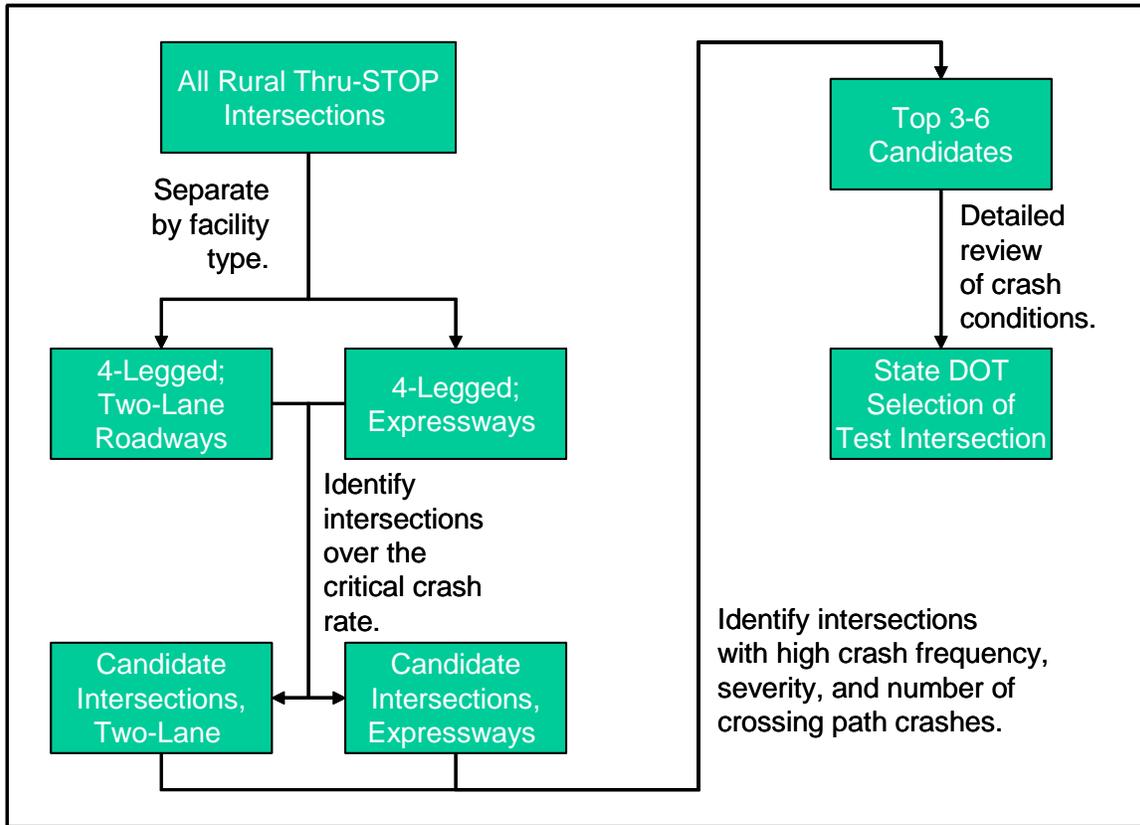


FIGURE 2-1
Preferred Crash Analysis Process

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 New Hampshire, 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, New Hampshire 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 State for all rural, thru-STOP intersections. (NOTE: In IDS studies of the states completed to date, most states elected to focus on expressway intersections because the traditional solution to a lag-selection crash problem is to install a traffic signal, which will have significant impacts on mobility. However, New Hampshire was the third state that chose to focus on rural two-lane roads in the search for candidate locations.)

The screening process in New Hampshire began with the New Hampshire Department of Transportation (NHDOT) providing a Geographic Information Systems (GIS) crash database for all crashes (January 1, 2003 through December 31, 2005) along with a GIS road network that included the physical attributes of the segments. Using GIS software, intersections crashes were queried if they occurred along a rural, two-lane US or State highway. Since the NHDOT is sponsoring the research project, it was believed appropriate that any locations considered should involve at least one roadway under their jurisdiction. Using the queried crashes, the 20 intersections with the highest crash frequency were identified; the result was all locations that had nine or more crashes during the three-year study period. To identify the final candidate locations from the potential 20 intersections (see Table 2-1), the following factors were considered:

- Four locations were eliminated because the intersection crash rate was below the computed critical crash rate.
- Four locations were eliminated as the traffic control device recorded from the officer report indicated the intersections have a traffic signal.
- After reviewing aerial photography, another four intersections were eliminated for geometry that eliminates some crossing maneuvers (i.e., T-intersection)
- Another location was eliminated because the aerial photography revealed the location was in an urban area.

Of the remaining seven locations, the intersections typically selected for further review would have had a high frequency of crossing path crashes. However, most reporting officers in New

Hampshire leave the field for crash diagram blank. Therefore, additional information from the Districts was requested. The information shared by the Districts revealed another four intersections could not be used in this study because significant improvements had been made for safety reasons (i.e., installing a traffic signal) or were programmed for the near future. This left the following three locations for the detailed analysis.

1. NH 101 & NH 123 in Hillsborough County*
2. NH 28 & NH 171 in Carroll County
3. NH 107 & NH 150 in Rockingham County

** Note: The District reported clearing of sight triangles had been done to improve intersection sight distance, but it was believed that this specific improvement would not significantly alter driver behavior, which would be collected in the next phase of this study.*

In previous states, the detailed analysis of the candidate location relied on information in the officer report, including the narrative. Because of confidentiality concerns, the officer reports were not made available by New Hampshire. Therefore, information was limited to that which is in the crash database. Furthermore, vehicle and driver information was only available for the first two years in the study period — January 1, 2003 through December 31, 2004. The lack of vehicle and driver information for the third year prevented some important elements of the analysis from being completed, specifically: creating collision diagrams to spot crossing path crashes, identification of at-fault driver, and crash location. Therefore, the following analysis was restricted to two years of data.

TABLE 2-1
New Hampshire Intersection Summary Table

Intersection of	County	Total Crashes	Entering ADT	Rate			Severity		
				Crash Rate	Expected Crash Rate	Critical Crash Rate	Fatal	Injury	PDO
US 3 and NH 25	Belknap	29	22930	1.2	0.4	0.6	0 0%	2 7%	27 93%
I-93 Ramps and US 3	Belknap	20	28436	0.6	0.4	0.6	0 0%	5 25%	15 75%
NH 101 and NH 123	Hillsborough	19	9696.5	1.8	0.4	0.8	0 0%	10 53%	9 47%
NH 106 and NH 140	Belknap	19	16604	1.0	0.4	0.7	0 0%	8 42%	11 58%
NH 125 and NH 152	Strafford	15	18221	0.8	0.4	0.7	0 0%	12 80%	3 20%
NH 140 and Main St.	Belknap	14	8291	1.5	0.4	0.8	0 0%	5 36%	9 64%
NH 155 and Madbury Rd.	Strafford	13	9350	1.3	0.4	0.8	0 0%	5 38%	8 62%
I-93 Ramps and NH 104	Belknap	12	11483.5	1.0	0.4	0.7	0 0%	1 8%	11 92%
NH 101 and Phelan Road	Hillsborough	12	17810	0.6	0.4	0.7	0 0%	4 33%	8 67%
US 4 and Main Street	Merrimack	12	18105	0.6	0.4	0.7	0 0%	4 33%	8 67%
NH 28 and Old Wolfeboro Road	Belknap	12	8180.5	1.3	0.4	0.8	0 0%	4 33%	8 67%
NH 28 and NH 171	Carroll	11	5624.5	1.8	0.4	0.9	0 0%	5 45%	6 55%
US 3 and NH 106	Belknap	11	22030	0.5	0.4	0.6	0 0%	3 27%	8 73%
US 302 and NH 16	Carroll	11	12976.5	0.8	0.4	0.7	0 0%	1 9%	10 91%
NH 10 and Base Hill Road	Cheshire	9	11580	0.7	0.4	0.7	0 0%	4 44%	5 56%
NH 106 and Pease Road	Belknap	9	7500	1.1	0.4	0.8	0 0%	3 33%	6 67%
NH 107 and NH 150	Rockingham	9	10246	0.8	0.4	0.8	0 0%	4 44%	5 56%
NH 9 and Washington Street	Cheshire	9	12461	0.7	0.4	0.7	0 0%	7 78%	2 22%
NH 3A and Hackett Hill Road	Merrimack	9	18250	0.5	0.4	0.7	0 0%	3 33%	6 67%
NH 27 and Main Street	Rockingham	9	5365	1.5	0.4	0.9	0 0%	4 44%	5 56%

NOTE:

- To calculate a critical crash rate, the statewide expected (i.e., average) crash rate for rural, thru-STOP intersections in New Hampshire was needed. This information was not available without a statewide database; therefore, the decision was made to use Minnesota's statewide rate (0.4 crashes per million entering vehicle [MEV]) to estimate the critical crash rate.
- Green highlighted rows indicate the three intersections analyzed in greater detail.

3. Crash Record Review of Candidate Intersections

It was already known that the three candidate intersections had high crash rates and high crash frequencies, but the decision was made to investigate each intersection further for 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 correctable crossing path crashes only (see following section for definition), which are the crash types that have the greatest potential to be corrected by the IDS system.

Special Note Regarding Crash Data Years: The initial crash analysis to select the three intersections was completed using three full years of crash data — 2003-2005. Yet, driver and vehicle information coded from the officer report is necessary for this detailed analysis, but was only available for the first two years. Therefore, the following analysis was limited to two years.

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).

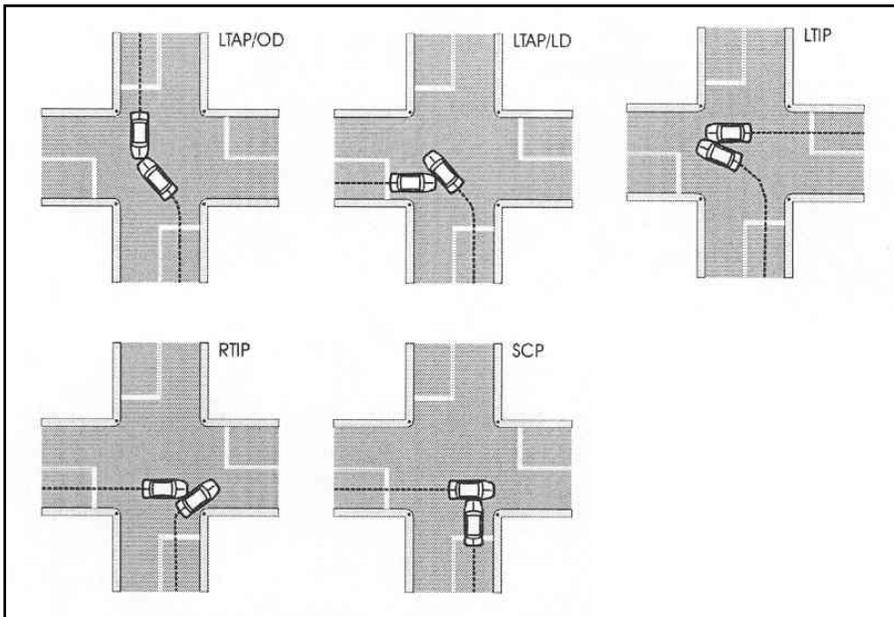


FIGURE 3-1
GES Crossing Path Crash Types

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 type at unsignalized rural intersections because they are a relatively small problem. However, it is believed the system could be adapted to address LTAP/OD crashes if an intersection had a significant number of these crashes. 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**. As shown in Table 3-1, approximately 55% or more of the crashes at the three candidate intersections are potentially correctable. Out of the three intersections, NH 101 & NH 123 had the greatest frequency and highest percentage of correctable crashes.

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

	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Crashes Totals: 2003-2005	19	11	9
Crashes Totals: 2003-2004	13	9	6
Number of Correctable Crashes (2003-2004)	10	5	4
Percent of Crashes that are Correctable (2003-2004)	77%	56%	67%

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

3.2. At-Fault Drivers

For each candidate intersection, all crash records from January 1, 2003 to December 31, 2004 were reviewed to identify the age of the driver whose action most likely caused the accident, also known as the at-fault driver (see **Figure 3-2**). The at-fault driver was determined using the contributing factor reported by the officer. The age of the at-fault driver is important since the IDS system may have its greatest benefit in assisting older drivers in particular.

Older drivers (age > 64-years) were classified as the at-fault driver in at least 20% of crossing path crashes at the candidate intersections. At NH 101 & NH 123, older drivers were determined to be the at-fault driver in half of all the crashes. However, one of the important issues to settle is if older drivers are over-represented in these crashes at the candidate locations. In previous analyses, the age distribution of “involved” drivers from individual states motor vehicle crash facts was used for a comparison. *Note: Age distributions in statewide crash reports list all involved drivers and not specifically at-fault drivers. This difference must be considered when making any comparisons.* However, the State of New Hampshire does not publish annual motor vehicle crash facts. But from the analysis in the previous five states (Iowa, Georgia, Michigan,

North Carolina, and Wisconsin); the involvement rate for older drivers has a range of 6% to 11%. This indicates that older drivers are over represented in crossing path crashes at the candidate locations. In fact, involvement of older drivers in crossing path crashes at NH 101 & NH 123 may be as much as five times greater than what would be expected.

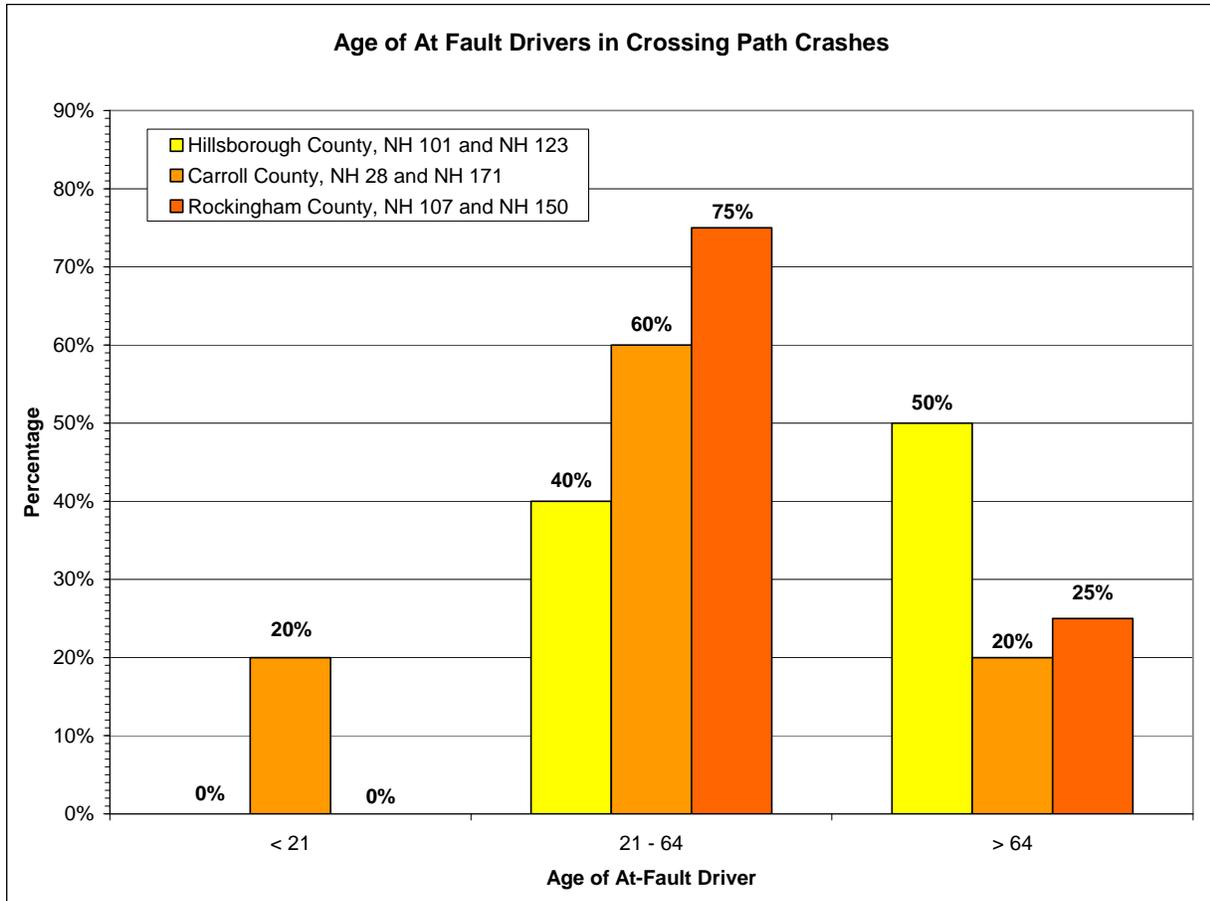


FIGURE 3-2
Age of At-Fault Drivers in Correctable Crash Types at the Candidate Intersections

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. As was the age distribution of drivers involved in a crash, the statewide crash severity distribution is not available without a state crash facts report. However, the analysis of previous states revealed that fatal crashes are typically less than 1% of all crashes and injury crashes may account for anywhere between 20% and 40%. **Figure 3-3** shows the crash severity distribution for the crossing path crashes between 2003 and 2004. While none of the intersections had a fatal crash during these two years, this is not entirely unexpected since fatal crashes would be expected to account for less than 1% of all crashes. At all three locations, an injury occurred in at least 50% of the crossing path crashes. Considering the range of the previous analyses, this indicates locations have an over representation of injury crashes. Once again, the intersection of NH 101 & NH 123 led the candidate locations with 70%

of crossing path crashes resulting in an injury. This supports the finding in the original IDS study (3) that crossing path crashes tend to be more severe than the average intersection crash.

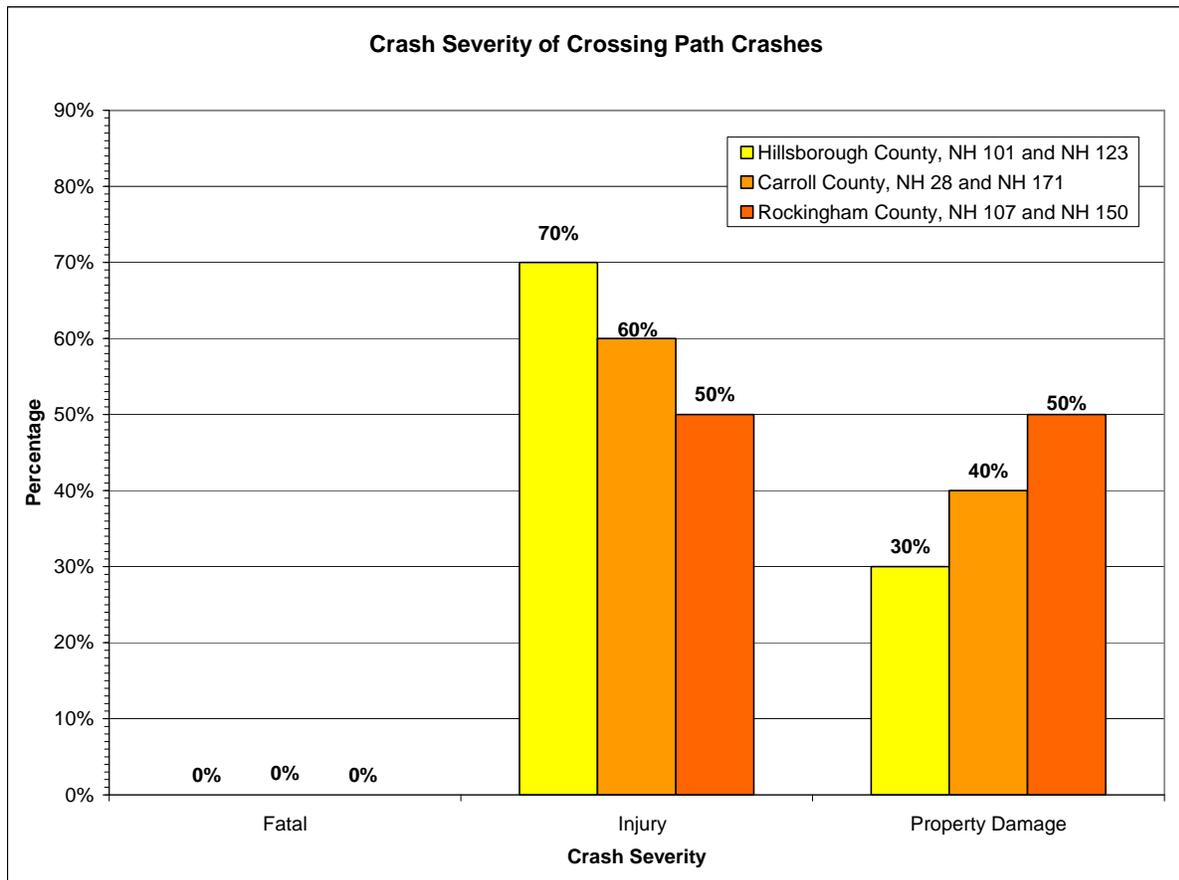


FIGURE 3-3
Crash Severity of Correctable Crash Types at the Candidate Intersections

3.4. Crash Location

From the initial review of Minnesota’s crash records (3), 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 proceed 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 crash data; all crashes recorded 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 split equally between far-side and near-side.

For the pooled fund study to date, rural expressway intersections in North Carolina, Wisconsin, and Iowa have been reviewed. For the candidate intersections in these states, the pattern was similar to what was observed in Minnesota with a majority of crossing path crashes occurring in the far lanes. The New Hampshire analysis differs slightly since the focus is on two-lane highways — Michigan and Georgia were the first two states to investigate intersections of two-lane highways. In the situation in New Hampshire, it is necessary for the driver to complete a crossing maneuver (i.e., straight across or left turn) in one step since there is no median refuge. However, documenting this crash characteristic is the first step to understanding the contributing circumstances and any differences between intersections on expressways and two-lane highways. Nevada will be the final state participating in the IDS Pooled Fund study that will focus on intersections of two-lane highways.

At the New Hampshire candidate intersections (see **Figure 3-4**), all three sites had one-half or more of the crossing path crashes occur on the far-side. The intersection with the highest percentage of far-side crashes is NH 107 & NH 150 in Rockingham County, where all crossing path crashes were located on the far-side.

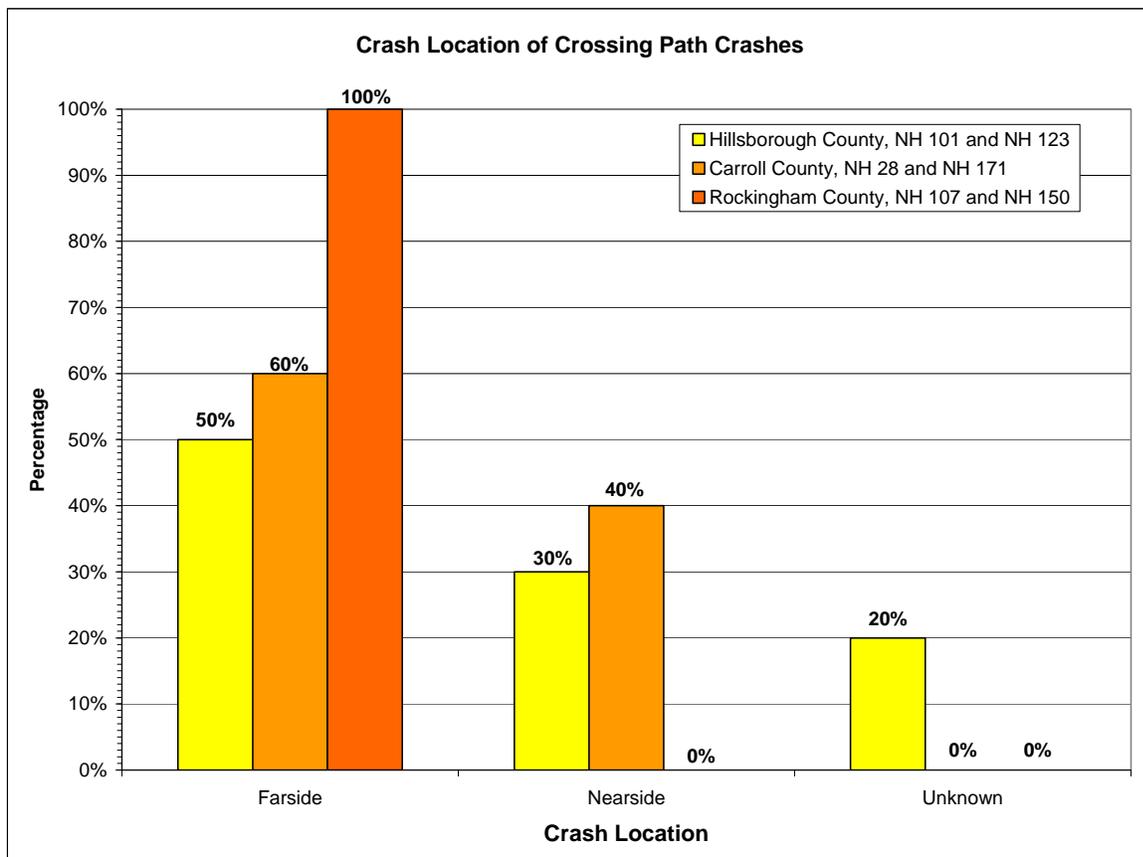


FIGURE 3-4
Crash Location of Correctable Crash Types at the Candidate Intersections

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 contributing factor reported in the crash database were used. If the officer reported the contributing factor as “Disregard Traffic Control Device,” then the crash was assumed to be caused by a problem with intersection recognition. If instead the contributing factor was “Failure to Yield ROW”, the crash was classified as lag recognition. Some drivers had contributing factors, such as “Physical Impairment”, which could not be used to classify the crash. In some cases, other factors may help indicate the type of crash, such as an at-fault driver that was turning onto the major road clearly recognized the intersection but instead failed to identify and select a safe lag. This scenario would have been classified as a lag recognition crash. Even with the secondary information, some crashes had to be classified as “unknown.”

As shown in **Figure 3-5**, at least 60% of the crossing path crashes at the intersections were lag recognition crashes. This strongly suggests that a high percentage of these crashes could have been prevented if the drivers had assistance in identifying, judging and selecting a safe lag.

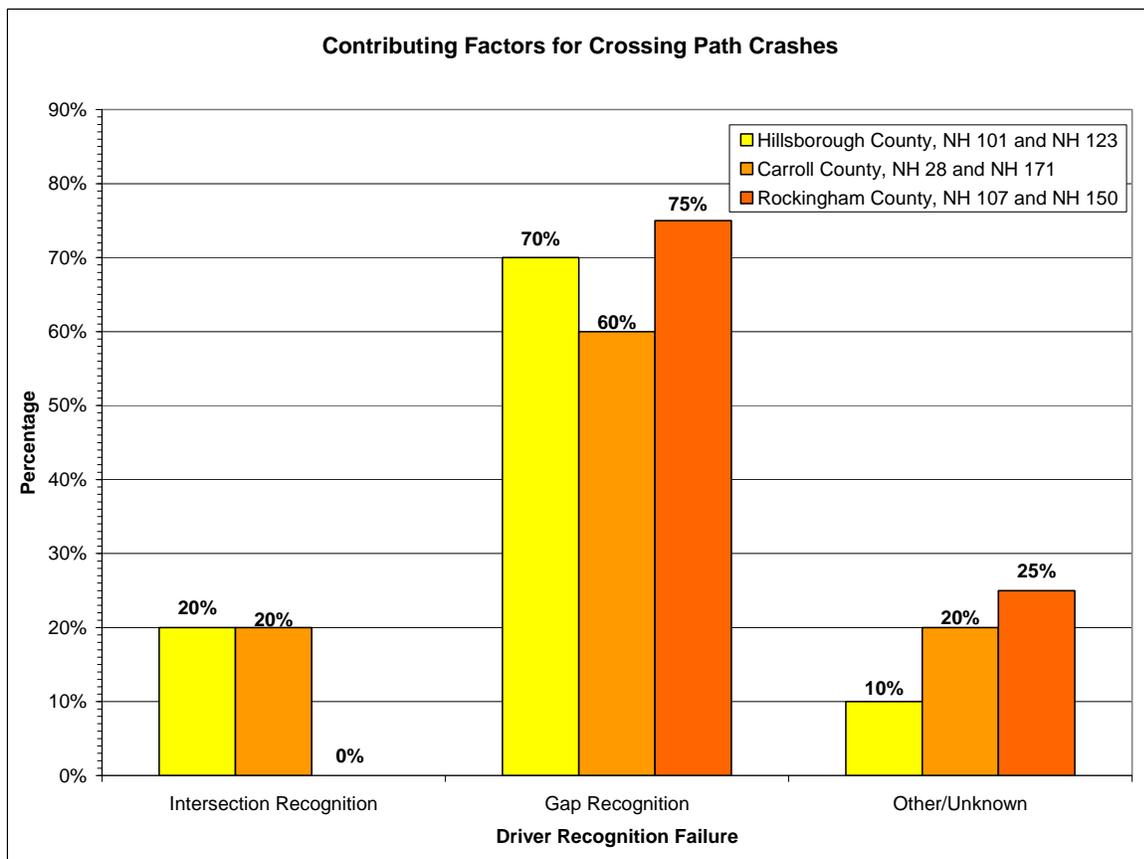


FIGURE 3-5
Contributing Factors of Correctable Crash Types at the Candidate Intersections

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.

Regarding the weather condition at the time of the crashes (see **Table 3-2**), all crossing path crashes occurred during good weather conditions. This indicates that weather was not a significant contributing factor to the crossing path crashes that occurred at the candidate intersections.

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

	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Clear or Cloudy	100%	100%	100%
Rain	0%	0%	0%
Snow or Sleet	0%	0%	0%

The road surface condition (see **Table 3-3**) was reported as dry except for one crash at the intersection of NH 107 & NH150. This single crossing path crash occurred on a wet pavement. This is another strong indication that adverse weather was not a casual factor in these crashes.

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

	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Dry	100%	100%	75%
Wet	0%	0%	25%
Snow or Ice	0%	0%	0%

The percentage of crossing path crashes reported during daylight conditions at all three intersections was at or above 80% (see **Table 3-4**), indicating dark or low-light driving conditions were not a substantial factor in the crossing path crashes.

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

	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Daylight	80%	80%	100%
Dawn or Dusk	0%	0%	0%
Dark	10%	20%	0%
Other/ Unknown	10%	0%	0%

4. Field Review

On August 1, 2007, field reviews for the three candidate intersections were performed. Participating in the field review were the District Engineer or Assistant District Engineer from the NHDOT. The public works director for the City of Peterborough, New Hampshire also participated in the field review for the intersection of NH 101 & NH 123 since the north approach is a city street. Some of the general observations made during the field review include:

- The typical minor street approach (stopped approach) at the candidate intersections was a single lane, and had one or more low-cost improvements implemented that were intended to address the crash problem. However, all of the improvements are designed to help drivers recognize the intersection and do not assist the driver in selecting a safe gap. (Note: Low-cost improvement deployed at the intersections included some or all of the following: intersection lighting, overhead red-yellow flashers, enhanced junction signing, turn lanes, two stop signs on an approach, and STOP AHEAD signs. These countermeasures will primarily aid drivers with intersection recognition.)
- Power is readily available at all intersections to operate an IDS system.
- Intersections are typically located on or near a horizontal or vertical curve. However, the intersection sight distance was typically at or above the recommended values.

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. NH 101 & NH 123 (Hillsborough County)

The intersection is located in Hillsborough County, on the eastern fringe of the community Peterborough (2000 Census Population = 5,883). NH 101 is the major road with the through approaches, generally running east-west in the Peterborough area and ultimately provides an east connection to Manchester or Nashua and the FE Everett Turnpike. Because of this, NH 101 is an important route for the local communities. NH 123 is the stopped approach from the south; and is also current with NH 101 to the west where the routes separate in Peterborough. The stopped approach from the north is Old Street Road, a city street under the jurisdiction of Peterborough.

In each intersection quadrant is located a residential property, but these properties are set back from the road and screened by trees, shrubs, and rock wall (see examples in **Figure 4-1**). Prior enhancements to the intersection include overhead red-yellow flasher (visible in **Figure 4-1** and **Figure 4-2**), street lighting in the northwest quadrant, and use of green-background guide signing on the NH 101 and NH 123 approaches (see **Figure 4-2**). Shortly before the field review, the NHDOT District improved the intersection sight triangles in the south quadrants. This mostly involved tree and shrub clearing with some regarding of the back slopes.

The intersection is located to the west of a horizontal curve on NH 101, which is shown in **Figure 4-3**. Despite the horizontal curve, adequate sight distance is currently provided for the posted speed limit, which is 50 mph to the east and 40 mph to the west of the intersection. However, the actual intersection sight distance before the improvements is not known. Also notable is that NH 101 is on a grade, with westbound traffic required to slow down to 40 mph while going downgrade when approaching the intersection.



FIGURE 4-1
Residential Properties in the Northeast (left photo) and Northwest (right photo) Quadrants



FIGURE 4-2
Guide Signing on the South (left photo) and East (right photo) Approaches



FIGURE 4-3
NH 101 Horizontal Curve Seen from North (left photo) and South (right photo) Approaches

The crash diagram in **Appendix A** reveals that all of the correctable crash types (i.e., right angle crashes) involved a thru vehicle on the east approach (Note: The east approach has the horizontal curve and vehicles going downgrade) and at least six of the at-fault drivers were entering the intersection from the south approach. The horizontal curve and higher approach speeds (compounded by the downgrade) may explain the over involvement of westbound vehicles. The higher approach volumes on the south approach in addition to the sight distance that was recently improved may account for the over involvement of at-fault drivers on the south approach.

4.2. NH 28 & NH 171 (Carroll County)

The intersection of NH 28 and NH 171 is located to the west of Ossipee (2000 Census Population = 4,211) in Carroll County. The uncontrolled approaches are NH 28, which is a north-south route with a posted speed limit of 55 mph. The east-west crossing route, NH 171, has stop controlled approaches on both sides of the intersections.

Adjacent to the intersection are three small business, a family medical practice and two law offices, which also appear to serve as the business owner's home (see **Figure 4-4**). Improvements made to the intersection include overhead red-yellow flasher, street lighting in the southeast quadrant (see **Figure 4-5**), left-turn lanes and channelized right-turn lanes on the NH 28 approaches, and double mounted Stop signs on the west approach (see **Figure 4-6**).



FIGURE 4-4

Small Businesses Adjacent to the Intersection of NH 28 & NH 171

The intersection is located to the south of a combined vertical crest and horizontal curve on NH 28, which is shown in **Figure 4-7**. Despite the horizontal curve, adequate sight distance is currently provided for the posted speed limit. Yet, four of the five crossing path crashes in the collision diagram (see **Appendix A**) involved a vehicle approach from the direction of the horizontal-vertical curve. As shown in **Figure 4-8**, a sag vertical curve combined with a tangent alignment provides nearly one-half mile of sight distance.



FIGURE 4-5
Intersection Lighting
in Southeast
Intersection Quadrant



FIGURE 4-6
Dual Stop Signs on
West Approach



FIGURE 4-7
Vertical Crest and Horizontal Curve North of Intersection Viewed from West (left photo) and
East (right photo) Approaches



FIGURE 4-8
NH 28 South
Approach — View
Looking Away from
Intersection

4.3. NH 107 & NH 150 (Rockingham County)

The intersection of NH 107 & NH 150 is located near the town of Kensington (2000 Census Population = 1,893). The uncontrolled approaches are NH 150, which is a north-south route with a posted speed limit of only 35 mph. The east-west crossing route, NH 107, has stop controlled approaches on both sides of the intersections.

In the land adjacent to the intersection is an auto-body repair shop in the southeast quadrant and a residential home in the northeast quadrant. Improvements made to the intersection include overhead red-yellow flasher, green-background guide signing on the NH 101 and NH 123 approaches (see **Figure 4-9**) and Stop-Ahead sign on the west approach (see **Figure 4-10**).

While the area is relatively flat, the intersection is located on a horizontal curve (see Figure 4-11). But drivers that pull slightly past the stop bar still have sufficient sight distance to see oncoming vehicles.



FIGURE 4-9
Guide Signing on the
East Approach



FIGURE 4-10
Stop-Ahead Sign on
the West Approach



FIGURE 4-11
Horizontal Curve in
NH 150 Alignment

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 New Hampshire candidate intersections.

- NHDOT has applied various safety countermeasures in the traffic safety toolbox at these intersections. It appears these countermeasures (minor street improvements such as STOP AHEAD sign, street lights, overhead yellow flashers, dual stop signs and advance guide and route signs) have been very effective at reducing intersection recognition crashes at many of these locations, but have not been effective at addressing lag related crashes – a crash type which is over represented at the candidate intersections.
- The crash characteristics for the subset of high crash frequency intersections examined are very similar to the data for comparable intersections in Minnesota. The intersections have a crash rate greater than the critical crash rate (statistically significantly different than the expected value), the distribution of crash types is skewed to angle crashes, lag related, more severe than expected, and typically not caused by weather and/or light conditions.
- There is a complicating geometric or traffic pattern at all three intersections – either a crest vertical curve or a horizontal curve. However, the actual intersection sight distance at each intersection appears to be consistent with AASHTO guidelines.

5.1. Recommended Intersection for Deployment

Of the candidate intersections, NH 101 & NH 123 is the recommend location for the next phase of the study — temporary deployment of the vehicle surveillance system to monitor driver behavior. NH 101 & NH 123 was selected for various reasons; the intersection had the highest frequency of crossing path crashes, the greatest percentage of crossing path crashes; the highest percentage of crossing path crashes resulting in an injury, the highest percentage of at-fault older drivers, and the greatest frequency of crossing path crashes where the driver error was attributed to selection of an unsafe lag.

Note: A resident from a property adjacent to the selected location raised concerns that the vehicle surveillance equipment may have negative health impacts. In response, the data collection of driver behavior in New Hampshire was cancelled.

5.2. Other Recommendations

If the IDS system is only deployed at NH 101 & NH 123, the remaining candidate intersection with no programmed improvements may benefit from traditional mitigation strategies to address any safety issues. A typical solution to address right angle crash problems is installation of a traffic signal. But for various reasons – steep grades at some locations, limited sight distance on some approaches, and rural location – a traffic signal would not be considered a desirable solution. There fore, the following recommendation is presented for NHDOT’s consideration. However, further investigation is required to determine if this recommendation is a feasible solution or if another strategy may be optimal.

TABLE 5-1
New Hampshire Intersection Summary

Performance Measure	NH 101 & NH 123 (Hillsborough County)	NH 28 & NH 171 (Carroll County)	NH 107 & NH 150 (Rockingham County)
Crash Frequency*	19	11	9
Crash Severity			
Fatal	0 (0%)	0 (0%)	0 (0%)
Injury	10 (53%)	5 (45%)	4 (44%)
PDO	9 (47%)	6 (55%)	5 (56%)
Daily Entering ADT	9,700	5,625	10,250
Crash Rate	1.8	1.8	0.8
Expected Rate	0.4 (MN)	0.4 (MN)	0.4 (MN)
Critical Crash Rate	0.8	0.9	0.8
Correctable Crash Type*	10 (77%)	5 (56%)	4 (67%)
Crash Severity			
Fatal	0 (0%)	0 (0%)	0 (0%)
Injury	7 (70%)	3 (60%)	2 (50%)
PDO	3 (30%)	2 (40%)	2 (50%)
At-Fault Driver			
< 21	0 (0%)	1 (20%)	0 (00%)
21 – 64	4 (40%)	3 (60%)	3 (75%)
> 64	5 (50%)	1 (20%)	1 (25%)
Unknown	1 (10%)	0 (0%)	0 (0%)
Crash Location			
Farside	5 (50%)	3 (60%)	4 (100%)
Nearside	3 (30%)	2 (40%)	0 (0%)
Unknown	2 (20%)	0 (0%)	0 (0%)
Contributing Factors			
Int Recg	2 (20%)	1 (20%)	0 (0%)
Gap Recg	7 (70%)	3 (60%)	3 (75%)
Unknown	1 (10%)	1 (20%)	1 (25%)

* Based on crash data from January 1, 2003 through December 31, 2005

♦ Based on crash data from January 1, 2003 through December 31, 2004

To increase the awareness of the driver on the major road when approaching the intersection, dynamic mainline flashers (as seen in North Carolina, Figure 5-1) could be added. These flashers can make the driver on the major road more aware when a vehicle is entering the intersection, possibly alerting the driver so that they can take action to avoid a collision. In North Carolina's use of this device, the flashers on the warning sign activate only when a vehicle is detected on the minor-street approach.

The final recommendation is that NHDOT consider creating an electronic database that has key intersection attributes (i.e., entering ADT volumes, roadway design, posted speed limit, area type, traffic control device, etc.) which can be queried and is also linked to the crash record

database. Development of such a tool would allow the State to quickly and reliably screen through many intersections in order to determine expected rates and identify high crash locations.



FIGURE 5-1
Example Dynamic
Mainline Flasher
(North Carolina)

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, 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. H. Preston, R. Storm, M. Donath, 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.)
4. T. Maze, N. Hawkins, G. Burchett. *Rural Expressway Synthesis of Practice and Crash Analysis*. CTRE Project 03-157. (Ames: Iowa Department of Transportation. October 2004.)

Appendix A
Intersection Crash Diagrams

Collision Diagram

Location: NH 101 & NH 123 (Hillsborough County)

Time Period: 01/01/2003 - 12/31/2004

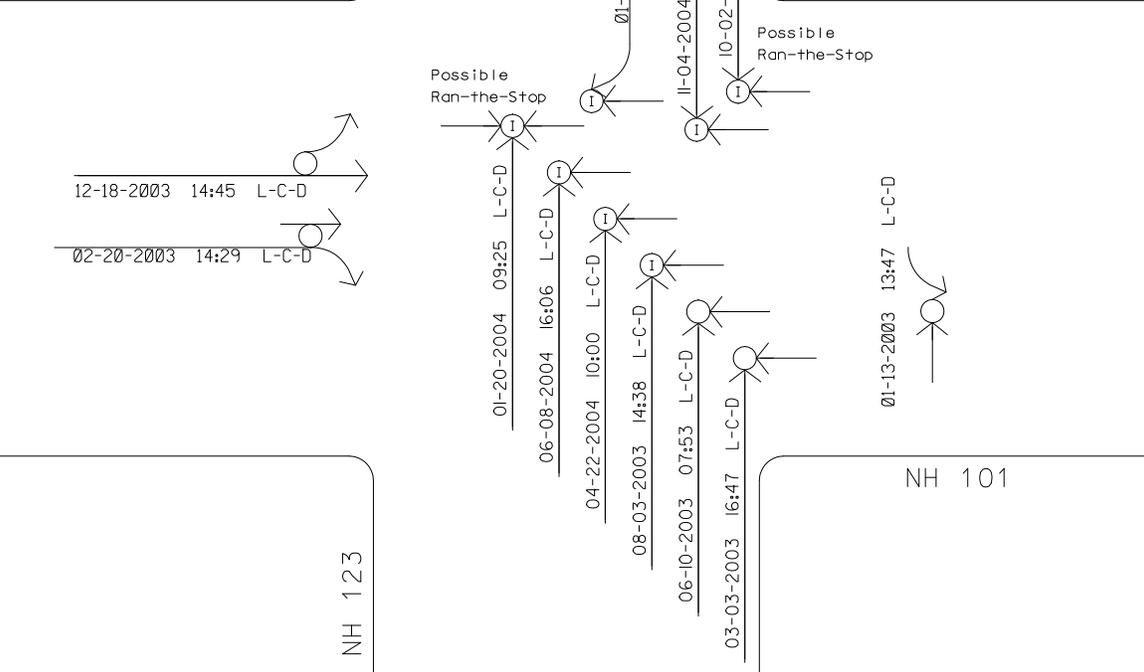
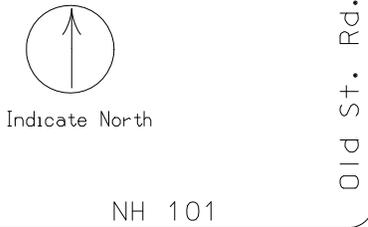
Prepared By: rjs

Date: 07-26-2007

No. of Accidents

Fatal=	0
Injury Total=	10
Property Damage=	9
Total Accidents=	19

6 crashes from 2005 and 1 right angle crash from 2003 could not be located.



→	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:

Injury Type Date Time Light-Weather-Surface

Collision Diagram

Location: NH 28 & NH 171 (Carroll County)

Time Period: 01/01/2003 - 12/31/2004

Prepared By: rjs

Date: 07-26-2007

No. of Accidents

Fatal= 0

Injury Total= 5

Property Damage= 6

Total Accidents= 11

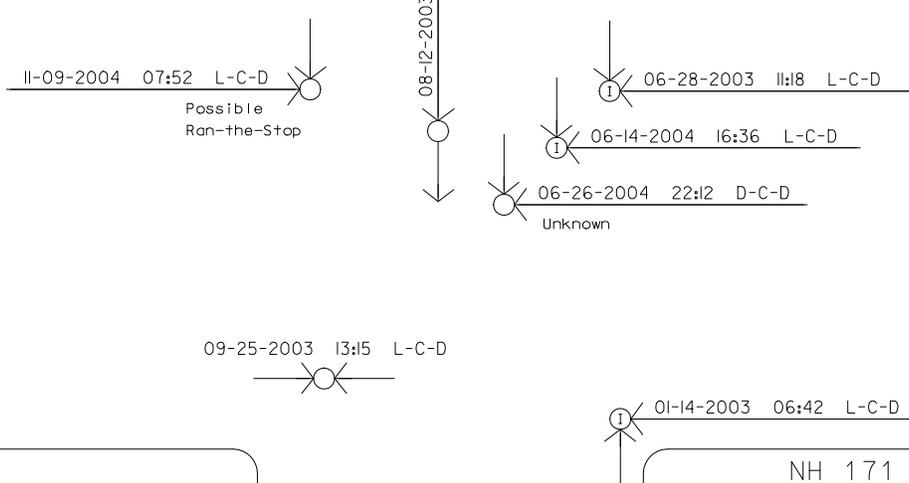
2 crashes from 2005 and
2 crashes from 2003
could not be located.



NH 171

NH 28

L-R-W
I516
08-12-2003



NH 28

NH 171

<ul style="list-style-type: none"> → Motor Vehicle Ahead ←←← Motor Vehicle Backing Up ⊞ Motor Vehicle Out of Control ⊙ Pedestrian ⊙ Bicycle/Moped ⊙ Motorcycle □ Fixed Object ● Fatal Acc. ⊙ Injury Acc. 	<p>Light:</p> <p>L= Daylight DN= Dawn Du= Dusk D= Dark X= Unknown</p>	<p>Weather:</p> <p>C= Clear or Cloudy R= Rain S= Snow or Sleet X= Other or Unknown</p>	<p>Surface:</p> <p>D= Dry W= Wet S= Snow or Ice X= Other or Unknown</p>	<p>Example of Bicycle/Motor Vehicle Accident:</p>
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Collision Diagram

Location: NH 107 & NH 150 (Rockingham County)

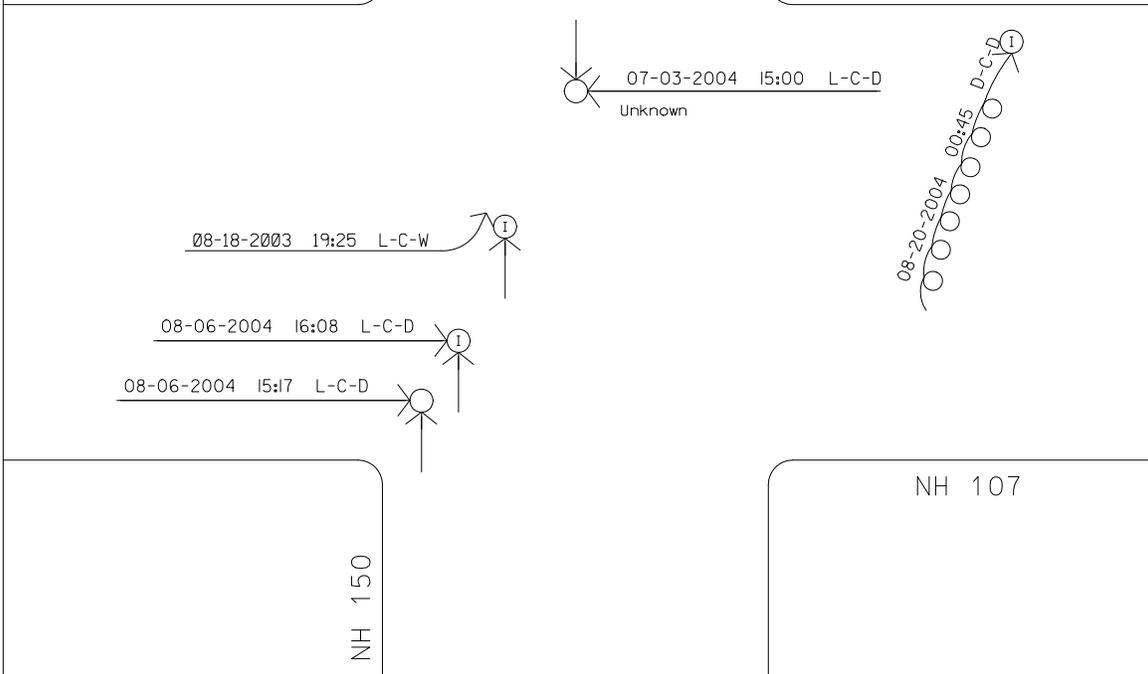
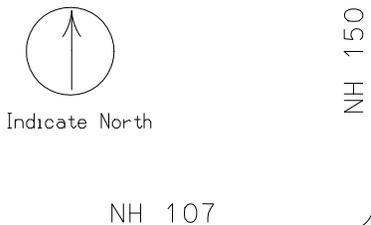
Time Period: 01/01/2003 - 12/31/2004

Prepared By: r.js Date: 07-26-2007

No. of Accidents

Fatal=	0
Injury Total=	4
Property Damage=	5
Total Accidents=	9

3 crashes from 2005 and 1 crash from 2004 could not be located.



→ Motor Vehicle Ahead	• Location/Details Unclear
⇐→ Motor Vehicle Backing Up	○ Property Damage Acc.
⊞→ Motor Vehicle Out of Control	⊞→ Rear End Property Damage
⊞ Pedestrian	⊞ Right Angle Injury
⊞ Bicycle/Moped	
⊞ Motorcycle	
□ Fixed Object	
● Fatal Acc.	
⊙ Injury Acc.	

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:

Appendix B
Aerial Photographs

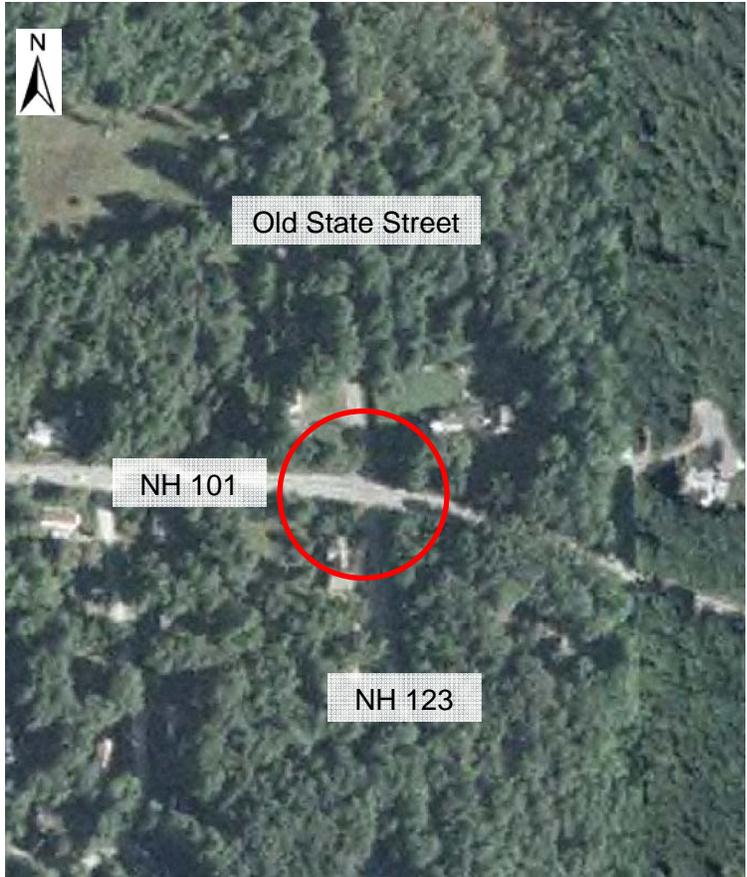


FIGURE B-1
Aerial Photo of NH 101 &
NH 123 (Hillsborough
County)

Source: New Hampshire DOT

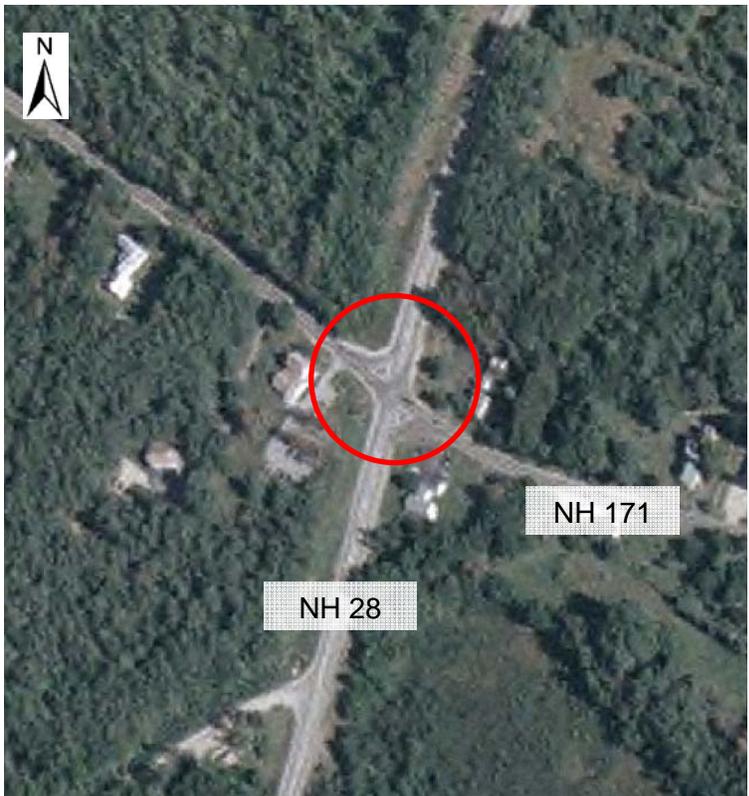


FIGURE B-2
Aerial Photo of NH 28 &
NH 171 (Carroll County)

Source: New Hampshire DOT

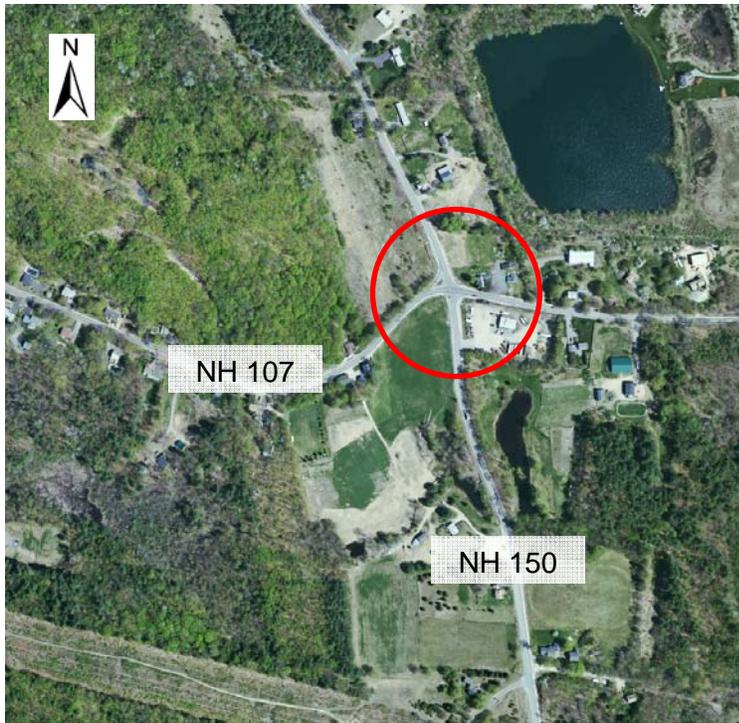


FIGURE B-3
Aerial Photo of NH 107 & NH
150 (Rockingham County)

Source: New Hampshire DOT