

Analysis of Median Crossover Crashes in Wisconsin

Research Report 2005-001

June 2005



TRAFFIC OPERATIONS AND SAFETY LABORATORY
University of Wisconsin-Madison
Department of Civil and Environmental Engineering

1. Report No. FHWA/WisDOT	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle ANALYSIS OF MEDIAN CROSSOVER CRASHES IN WISCONSIN		5. Report Date June 30, 2005	
		6. Performing Organization Code	
7. Author/s David A. Noyce and Regan J. McKendry		8. Performing Organization Report No. 2005-01	
9. Performing Organization Name and Address TRAFFIC OPERATIONS AND SAFETY LABORATORY University of Wisconsin-Madison Department of Civil and Environmental Engineering 1415 Engineering Drive, Madison, WI 53706		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. 144-MP71	
12. Sponsoring Organization Name and Address Wisconsin Department of Transportation 4802 Sheboygan Ave. Madison, WI 53705		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes Project performed in cooperation with the Wisconsin Department of Transportation and the Federal Highway Administration			
16. Abstract A total of 15,194 crash reports were reviewed for the three-year period, revealing 631 median crossover crashes in Wisconsin. The crashes resulted in over 600 injuries and 53 fatalities. A majority of the roadways examined have either 50 feet or 60 feet median widths. Current Wisconsin guidelines do not require a median barrier for roadways with a median width greater than 60 feet. Other characteristics of crossover median crashes were statistically examined, including total vehicles involved, crash vehicle type, crash severity, roadway geometry, initial causation of crash, age of driver, and presence of alcohol. Crashes were plotted on a statewide highway map. Data did not reveal a strong correlation between median width and crossover median crashes. Both roadways with narrow and wide median widths exhibited varying median crash rates. Five locations were identified that exceeded the benchmark of 0.5 median crossover crashes per mile per year. One location exceeded the benchmark of 0.12 median crossover fatalities per mile per year. Information from the Crash Outcome Data Evaluation System (CODES) was used to quantify the costs of median crossover crashes in comparison to crashes with a median barrier. Median crossover crashes were found to cost, on average, \$39,000 more per occupant than similar median barrier crashes. The cost of crossover crashes, in terms of medical costs, exceeds median barrier impact crashes by approximately \$19 million per year.			
17. Key Words Median, Crossover, Crashes, Wisconsin, CODES	18. Distribution Statement No restrictions.		
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. Of Pages 140	22. Price

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Research Project Number 144-MP71
Study Title: Work Order 11 – Median Crossover Crashes and CODES Analysis

Sponsored by the
Wisconsin Department of Transportation
In cooperation with
U.S. Department of Transportation
Federal Highway Administration

July, 2005

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ACKNOWLEDGEMENTS

This research project was conducted under a cooperative program between the Traffic Operations and Safety (TOPS) Laboratory, Wisconsin Department of Transportation, and the U.S. Department of Transportation, Federal Highway Administration. The authors acknowledge and appreciate the guidance of the WisDOT project director for this research, Mr. Dick Lange. The contributions of John Corbin, Wisconsin State Traffic Engineer, and Todd Szymkowski, Xiao, Qin, Jeff Guenette and George Lu of the TOPS lab are gratefully acknowledged.

ABSTRACT

The Wisconsin Department of Transportation (WisDOT) sought to determine the magnitude of median crossover crashes on Wisconsin's divided highways. A survey was conducted of crash reports for 1,483 miles of freeways and expressways from 2001 through 2003 to quantify median entry crashes and median crossover crashes. Selected crashes were documented and electronic images of the crash report produced. Median width and ADT data were collected for each selected crash site and added to the data obtained from the crash report. It was hypothesized that a relationship existed between median width, ADT, and median crossover crash frequency, such that as the median width increased, median crossover crash frequency would decrease.

A total of 15,194 crash reports were reviewed for the three-year period, revealing 631 median crossover crashes. The crashes resulted in over 600 injuries and 53 fatalities. A majority of the roadways examined have either 50 or 60 feet median widths, as per Wisconsin standards. Current Wisconsin guidelines do not warrant a median barrier for a roadway with a median width greater than 60 feet. Nevertheless, 81.5 percent of the median crossover crashes identified occurred at ADT and median width combinations where a median barrier is not warranted.

Data did not reveal a strong correlation between median width and crossover median crashes. Both roadways with narrow and wide median widths exhibited varying median crash rates. Other characteristics of crossover median crashes were statistically examined, including total vehicles involved, crash vehicle type, crash severity, roadway geometry, initial causation of crash, age of driver, and presence of alcohol. Crashes were plotted on a statewide highway map and spatially analyzed to establish high concentration locations of crossover median crashes. Five locations were identified that exceeded the benchmark of 0.5 median crossover crashes per mile per year:

- I-39/I-90/I-94 in Columbia and Dane Counties
- I-94 in Dunn County
- USH 41 in Fond Du Lac, Winnebago, and Brown Counties
- USH 53 in La Crosse County
- USH 151 in Dane and Dodge Counties

One location exceeded the benchmark of 0.12 median crossover fatalities per mile per year:

- I-39/I-90/I-94 in Columbia and Dane Counties

Information from the Crash Outcome Data Evaluation System (CODES) was used to quantify the costs of median crossover crashes in comparison to crashes with a median barrier. Median crossover crashes were found to cost, on average, \$39,000 more per occupant than similar median barrier crashes. The CODES analysis found that the cost of crossover crashes, in terms of medical costs, exceed median barrier impact crashes by approximately \$19 million per year.

It is recommended that median barrier installation be considered at the five locations identified. After installation, research should be conducted to evaluate the number of barrier hits and associated maintenance costs. It is also recommended that the procedure used to warrant median barrier installation be reconsidered.

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CHAPTER I INTRODUCTION

Over the four year period from 2000 to 2003, 169,789 people lost their lives on America's roadways (1). In 2003 alone, 42,643 people were killed. Of the 42,643 fatalities in 2003, over 25,000 died when their vehicle departed from their travel lane and crashed. Lane departure or run-off-road (ROR) crashes are associated with vehicles that leave the travel lane, encroach onto the shoulder and beyond, and hit one or more of any number of objects including opposing vehicles, bridge walls, poles, embankments, guardrails, parked vehicles, or trees (2). ROR crashes usually involve only a single vehicle, and consist of a vehicle encroaching onto the right shoulder and roadside, on the median side where the highway is separated, or on the opposite side when the vehicle crosses the opposing lanes of a highway. In recent years, approximately 55 percent of traffic fatalities were a result of ROR type crashes (3). Approximately 40 percent of fatal crashes were single-vehicle ROR crashes.

Over that same four-year period, 3,206 people were killed in traffic crashes on Wisconsin's roadways, representing approximately 1.9 percent of the nation's total (4). In 2003 alone, Wisconsin experienced 836 fatalities in 748 fatal crashes. Wisconsin is also no exception to the high number of ROR crashes experienced nationally. A recent study found that approximately 54 percent of all non-intersection crashes on undivided roadways in Wisconsin were ROR type crashes (5). This number may be even higher on the divided roadway system.

Crashes in Wisconsin are documented by County Sheriffs, local Police, or State Patrol Troopers on the Wisconsin Motor Vehicle Accident Report (WMVAR). The form contains a variety of data from each crash that is scanned and then archived into searchable databases: location and time of day, drivers and vehicles involved, weather and road conditions, presence of alcohol, and type of accident. Figures 1 through 4 display these sections.

The type of accident field divides crashes into three classes: collision with object not fixed, collision with fixed object, and non-collision, with various sub-categories. This field is displayed in Figure 4. Absent from the form, however, is a field to enter specific crash types related to ROR crashes. Specifically, the crash form does not allow for detailed reporting of crashes that involve vehicles that enter median of divided highways or cross over the median of a divided highway and entered the opposing lane of traffic. Therefore, details pertaining to median crossover and related ROR crashes are obtained by manual searches of the narrative and diagrams provided in the accident report.

Medians of divided highways are an important design and traffic safety feature when considering ROR crashes. The American Association of State Highway Transportation Officials (AASHTO) defines a median as the "portion of a highway separating directions of the traveled way" (6). AASHTO's *A Policy on Geometric Design of Highways and Streets* states that "medians are highly desirable on arterials carrying four or more lanes" of traffic (6). Separation of opposing volumes can be important in the attempt to prevent head-on collisions, one of the most potentially serious types of crashes.

Unit Number ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩		Unit Type ① ② ③ ④ ⑤ ⑥ ⑦		Total Number of Occupants ① ② ③ ④ ⑤ ⑥ Other <input type="text"/>		Direction of Travel (Before the Accident) N W E S	
Speed Limit ① ②	OPERATOR Last NAME 25			First		M.I.	
① ⑤	ADDRESS Street & Number 26						
②	City & State			ZIP	Phone Number ()		
③	27			28			
④	Driver's License Number			State	Exp. Year		
⑤ 24	29			30		31	
⑥	Date of Birth 32		Sex ① M ② F	Operating as Classified: 36	Class (Mark Only One) ① A ② D ③ B ④ M ⑤ C ⑥ O		Endorse (Mark All That Apply) ① H ② P ③ T ④ N ⑤ S ⑥ F
NA	On Duty Accident ① P Police ② E EMT/First Responder ③ F Fire Fighter ④ H Winter Hwy Maintenance 34		CMV ① Y ② N		35		
Severity ① K ② N ③ A ④ B ⑤ C	SEAT Position 38	SAFETY Equipment 39	AIRBAG ① Deployed ② Non Deployed ③ Not Applicable ④ Unknown		EJECTED ① Not Applicable ② Not Ejected ③ Totally Ejected ④ Partially Ejected ⑤ Unknown		
TRAPPED/ EXTRICATED	① Not Applicable ② Not Trapped	③ Trapped/Extricated ④ Trapped/Not Extricated	⑤ Unknown		Medical Transport ① Y ② N		
④	Vehicle Owner Same ① Y ② N		Last Name 45		First		M.I.
④	Street Address 47						
④	City & State			ZIP	Phone Number ()		
④	48			49			
Year of Vehicle	Make	Model	Body Style	Color			
50	51	52	53	54			
Vehicle ID Number 55							
License Plate Number 56				Plate Type 57	State 58	Exp. Year 59	

FIGURE 3 WI Crash Form – Driver and Vehicle Data.

Type of Accident		
<input type="checkbox"/>	First Harmful Event	80
Most Harmful Event		
Unit Number		Unit Number
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6
<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
<input type="checkbox"/> 10	81	<input type="checkbox"/> 10
(select one per vehicle)		
Collision With Object Not Fixed		
<input type="checkbox"/> 1	Motor Vehicle in Transport	<input type="checkbox"/> 1
<input type="checkbox"/> 2	Parked Motor Vehicle	<input type="checkbox"/> 2
<input type="checkbox"/> 3	Deer	<input type="checkbox"/> 3
<input type="checkbox"/> 4	Pedalcycle	<input type="checkbox"/> 4
<input type="checkbox"/> 5	Pedestrian	<input type="checkbox"/> 5
<input type="checkbox"/> 6	Railway Train	<input type="checkbox"/> 6
<input type="checkbox"/> 7	Other Animal	<input type="checkbox"/> 7
<input type="checkbox"/> 8	Motor Vehicle in Transport In Other Roadway	<input type="checkbox"/> 8
<input type="checkbox"/> 9	Other Object (Not Fixed)	<input type="checkbox"/> 9
Collision With Fixed Object		
<input type="checkbox"/> 10	Traffic Sign Post	<input type="checkbox"/> 10
<input type="checkbox"/> 11	Traffic Signal	<input type="checkbox"/> 11
<input type="checkbox"/> 12	Utility Pole	<input type="checkbox"/> 12
<input type="checkbox"/> 13	Lum. Light Support	<input type="checkbox"/> 13
<input type="checkbox"/> 14	Other Post	<input type="checkbox"/> 14
<input type="checkbox"/> 15	Tree	<input type="checkbox"/> 15
<input type="checkbox"/> 16	Mailbox	<input type="checkbox"/> 16
<input type="checkbox"/> 17	Guardrail Face	<input type="checkbox"/> 17
<input type="checkbox"/> 18	Guardrail End	<input type="checkbox"/> 18
<input type="checkbox"/> 19	Median Barrier	<input type="checkbox"/> 19
<input type="checkbox"/> 20	Bridge Parapet End	<input type="checkbox"/> 20
<input type="checkbox"/> 21	Bridge/Pier/Abut.	<input type="checkbox"/> 21
<input type="checkbox"/> 22	Impact Attenuator	<input type="checkbox"/> 22
<input type="checkbox"/> 23	Overhead Sign Post	<input type="checkbox"/> 23
<input type="checkbox"/> 24	Bridge Rail	<input type="checkbox"/> 24
<input type="checkbox"/> 25	Culvert	<input type="checkbox"/> 25
<input type="checkbox"/> 26	Ditch	<input type="checkbox"/> 26
<input type="checkbox"/> 27	Curb	<input type="checkbox"/> 27
<input type="checkbox"/> 28	Embankment	<input type="checkbox"/> 28
<input type="checkbox"/> 29	Fence	<input type="checkbox"/> 29
<input type="checkbox"/> 30	Other Fixed Object	<input type="checkbox"/> 30
<input type="checkbox"/> 31	Unknown	<input type="checkbox"/> 31
Non-Collision		
<input type="checkbox"/> 32	Overturn	<input type="checkbox"/> 32
<input type="checkbox"/> 33	Fire/Explosion	<input type="checkbox"/> 33
<input type="checkbox"/> 34	Immersion	<input type="checkbox"/> 34
<input type="checkbox"/> 35	Jackknife	<input type="checkbox"/> 35
<input type="checkbox"/> 36	Other Non-Collision	<input type="checkbox"/> 36

FIGURE 4 WI Crash Form – Type of Crash.

Medians generally consist of a vegetated area of land and the interior shoulders of the travel lanes placed between opposing traffic flows. For freeways, a shallow depressed slope, generally one-foot vertical to four-foot horizontal, or flatter, is typically preferred for drainage and to minimize the probability of a rollover during a crash should a vehicle enter the median. Various combinations of median width and slope may be supplemented with a median barrier if conditions warrant. A median barrier is a system erected to decrease the probability of a vehicle crossing over the median into the path of vehicles traveling in the opposing direction (6). Examples of selected median barriers are presented in Figure 5.

AASHTO has design guidelines but no specific standards regarding median width. For medians 40 feet or wider, AASHTO states that drivers are given a “sense of separation from opposing traffic” and a “desirable ease and freedom of operation.” Medians 60 feet in width or wider have the potential to be landscaped in a park-like manner (6). The Facilities Development Manual (FDM) for the Wisconsin Department of Transportation (WisDOT) specifies a minimum median width of 60 feet for all Design Class A3 freeways and Design Class A3 expressways with a speed limit greater than 55 miles per hour (mph); a minimum median width of 50 feet for all Design Class A3 expressways with speed limits of 50 or 55 mph (7). A Design Class A3 highway is an arterial with a minimum volume of 7,000 vehicles per day (vpd) and a minimum design speed of 65 mph (8). Typical medians used on Wisconsin highways are presented in Figures 6 and 7. Figure 8 depicts a typical cross section of a 4-lane Design Class A3 highway, with a 50 or 60 foot median.

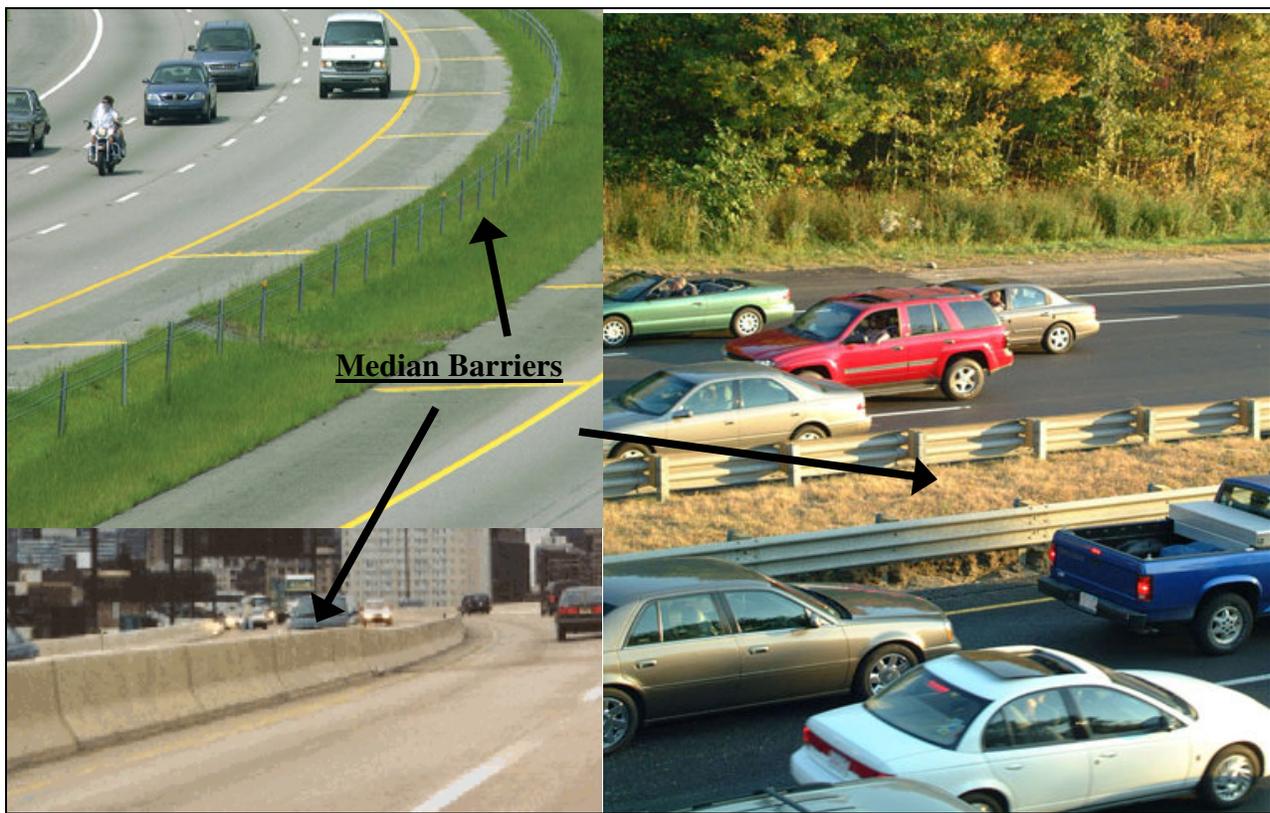


FIGURE 5 Typical Median Barriers.



FIGURE 6 Typical Wisconsin Highway Median (I-39 Rock County – 60 feet).



FIGURE 7 Typical Wisconsin Highway Median (USH 14 Dane County – 68 feet).

It is believed that these median slope and width standards are adequate in providing sufficient vehicle recovery space to maximize safety and in preventing vehicles from traveling across the median into opposing lanes of traffic. However, there are numerous roadways throughout the state that do not meet these standards (i.e., a narrower median width) and do not provide any additional safety features such as median barriers. As depicted in Figure 9, state guidelines do not warrant a barrier for median widths greater than 60 feet. A barrier is also not warranted for medians widths as narrow as 20 feet when average daily traffic volumes are less than 20,000 vehicles per day. It is not well understood whether the current median barrier warrant guidelines are sufficient in maximizing the safety of divided highways in Wisconsin.

Problem Statement

Median crossover crashes are increasing in frequency across the United States, and Wisconsin is believed to be no exception to this trend. However, the magnitude of the median crossover crash problem is not well known, nor is the characteristics and causes of such crashes. Furthermore, the current median width guidelines and/or median barrier policy may no longer be adequate for today's traffic conditions. Studies have suggested that wider median widths are safer, but it is not well understood what median width is necessary to maximize the safety of a roadway.

The costs of median crossover crashes are also unclear, which makes the benefit/cost analysis of any proposed safety improvements difficult. Knowledge of these costs is not merely dependent on crash frequency. It is important to consider crash cost by injury severity when cost is of a primary concern (9). Understanding the possible significance of the median crossover crash problem and developing a solution is dependent on knowing the costs of the crashes versus the benefits gained through wider medians or median protection, such as a barrier.

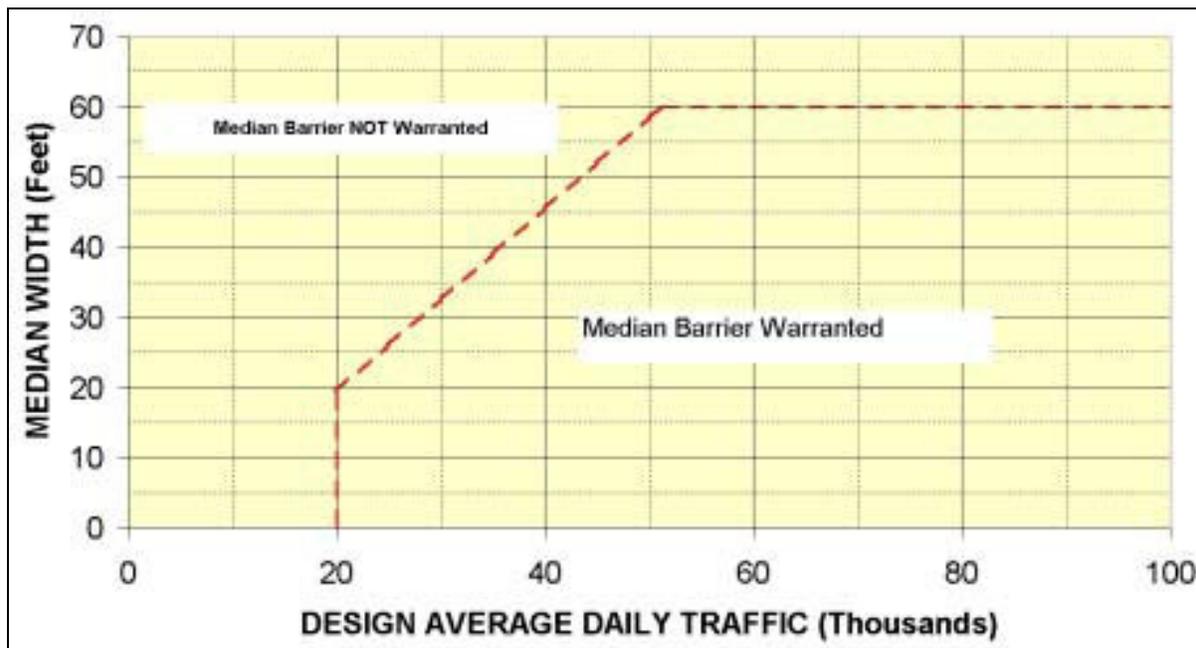


FIGURE 9 Wisconsin Median Barrier Warrant Guidelines (7).

The construction and material cost of any median-based improvements can be considered in relation to the human cost of crashes obtained from the Crash Outcome Data Evaluation System (CODES). CODES links cost data from each crash with other relevant crash data. These data typically consist of injury outcome data, including the type, severity, and cost of all injuries incurred by people in the crash, along with vehicle registration, driver licensing, citations, and roadway inventories data (10). The linkage of the data enables researchers and state officials to understand the specific injuries and costs of a crash based on driver, vehicle, and roadway characteristics.

Given the unknown frequency of median crossover crashes in Wisconsin, there is a need to determine the magnitude and severity of median crossover crashes and establish common characteristics and causes of these crash types. Additionally, the availability of CODES data can quantify the costs of median crossover crashes to aid in determining what safety improvements should be undertaken.

Research Objectives

The objective of this research was to investigate and evaluate the present state of median crossover crashes on Wisconsin freeways and expressways. Specific objectives were:

- Quantify the magnitude of median crossover crashes in Wisconsin;
- Establish a relationship between median width, traffic volumes, and crossover crashes;
- Identify the most critical factors affecting crossover crashes; and
- Evaluate the financial costs of crossover crashes and explore the benefit/cost ratios for median safety improvements.

Scope

The scope of this research was limited to crossover crashes on Wisconsin freeways and expressways from the period of 2001 to 2003. Most, but not all, divided highway sections in Wisconsin were considered. Highway sections with a median barrier were not considered in the crash analysis but included as a comparison database in the CODES analysis. Crashes that occurred where a vehicle broke through or vaulted over a median barrier, where a vehicle intentionally crossed over the median, or where an object crossed over the median that a barrier would not have prevented, were excluded from the analysis. Only data available through the Wisconsin crash records system were considered.

Organization of Report

This report is separated into six chapters as presented in Figure 10. Chapter 1 has presented an introduction to the relationship between median width and median crossover crashes. Chapter 2 presents past research on median width and median crossover crashes. Chapter 3 presents the experimental design of the research. Chapter 4 presents the research results and data analysis while Chapter 5 presents benefit/cost analysis related to CODES. Chapter 6 presents conclusions and recommendations.

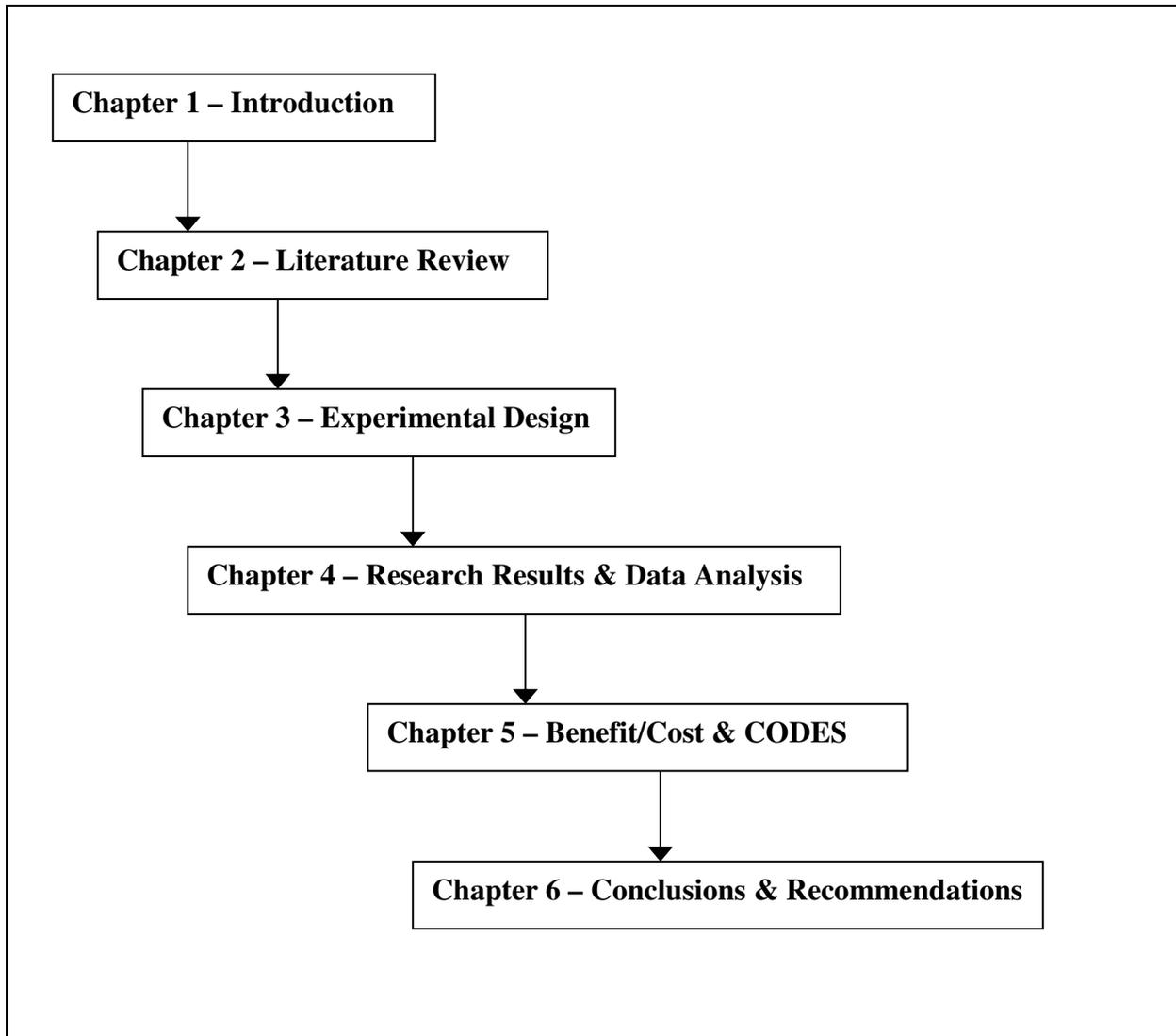


FIGURE 10 Organization of Report.

CHAPTER II LITERATURE REVIEW

Median areas to separate opposing traffic flows have long been an important safety feature of our roadways. As presented in Chapter I, median width is the distance between the edges of the opposing traveled way, including the interior shoulders. The American Association of State Highway and Transportation Officials (AASHTO) describes the principal functions of a median as separating opposing traffic, providing an area for vehicles to stop and regain control in an emergency, allowing space for turning lanes, minimizing headlight glare, and providing space for the addition of future lanes (6). These functions of a median are reiterated in the Wisconsin Facilities Development Manual (FDM). With regards to safety on expressways, the median's use as a divider of opposing traffic and as a recovery and resting area for vehicles that must leave the roadway is of primary interest to this research.

Median Width and Cross Section Design

Research on median width and cross section design has been conducted for more than 50 years. In the 1950's and 60's, Hutchinson and Kennedy studied stretches of Interstates 57 and 74 in Illinois. Patrolling the roadway in slow, marked vehicles over specified areas during certain times, teams of two documented the time, sketched dimensions, and photographed the location of each median incursion (11). The results of the research determined that a minimum median width of 30 ft should be used on all rural highways, and that the median should be obstacle-free with a mild (24:1 or greater) cross-slope. Hutchinson and Kennedy felt the median should be provided as a clear zone, defined by AASHTO as the "unobstructed, relatively flat area provided beyond the edge of the traveled way for the recovery of errant vehicles" (6). To this end, researchers felt that necessary obstacles in the median, such as culverts and earthen ditch checks, should be as few and infrequent as possible to pose the least amount of hazard and intimidation towards drivers entering the median (11).

The Georgia Institute of Technology (Georgia Tech) examined median crossover crashes through computer simulation in 1970. Wright, Hassell, and Arrillaga performed 432,000 trials, considering median widths of 10, 20, and 30 feet, with results indicating that the larger medians had a positive effect in reducing the severity of crossover crashes (12). Simulations looked solely at impact speed as no attempt of vehicle recovery was made. There was little change in speed of the crossover vehicle for all three median widths, leading researchers to feel that there is minimal time to react during a crossover event (12). A 30-foot median showed an 11 percent reduction in the median crossover rate as compared to a 10 foot median; however, the 30-foot median still had a crossover rate at nearly 50 percent.

Literature in this section shows some of the early research into effective and safe median design. The clear-zone concept that Hutchinson and Kennedy wrote about has become part of the standard definition of a median as stated by AASHTO: "[The principal functions of a median are to] provide a recovery area for out-of-control vehicles" (6). Computer simulations performed at Georgia Tech demonstrated that recommended median widths of 30 feet, though better than not having a median, were still inadequate at providing an acceptable level of safety. The next section presents further research into median widths and crash experiences.

Median Width and Overall Crash Improvement

Garner and Deen conducted research in 1973 for the Kentucky Department of Highways to examine median related crashes, both median crossover and median incursion, and to evaluate the recommended practices in regard to median width and slope (13). The previous two to four year crash histories for sections of Interstates 64, 65 and 75, along with the Kentucky Turnpike, Western Kentucky Turnpike, and Bluegrass Parkway, were evaluated. Researchers found evidence that a larger median both helped prevent median crossover crashes as well as provided a refuge for vehicles seeking to avoid a collision in their own travel lane (13). As median width increased, the crash rate and total crash severity decreased, with benefits diminishing at a median width between 30 and 40 feet (13). Traffic volumes were shown to have a small effect on the incidence of crashes, unless vehicular volumes were drastically different. Researchers recommended a 40-foot median. Results of the research are shown in Tables 1 and 2.

Research findings also indicated that deeply depressed medians were discouraged to prevent vehicle rollovers. Raised medians showed an increase in crashes in which a vehicle struck the median and then lost control. The use of raised medians was not recommended.

TABLE 1 Median Crashes Involving Vehicles that Overturn

Road	Median Width (ft)	Median Type	Percent of Median Crashes	Crash Rate (Crashes per 100 Million VMT)
Kentucky Turnpike	20	Raised	10.7	2.88
Western Kentucky Turnpike	30	Raised	24.0	4.75
I-64 & I-65	60	Depressed	20.1	2.42
Bluegrass Parkway	36	Depressed, 4:1 slopes	34.7	10.31
Mountain Parkway	36	Depressed, 3:1 slopes	46.0	16.47

TABLE 2 Median Crashes Involving Vehicles that Hit the Median and Lost Control

Road	Median Width (ft)	Median Type	Left Shoulder Width (ft)	Percent of Median Crashes	Crash Rate (Crashes per 100 Million VMT)
Kentucky Turnpike	20	Raised	4	19.2	5.16
Western Kentucky Turnpike	30	Raised	4	30.2	5.99
I-64 & I-65	60	Depressed	6	16.5	1.99
Bluegrass Parkway	36	Depressed, 4:1 slopes	6	11.2	3.34
Mountain Parkway	36	Depressed, 3:1 slopes	10	4.8	1.70

In 1993, researchers at the University of North Carolina and University of Western Australia conducted a statistical review of the relationship between median width and crash rates for highway segments in Illinois and Utah. Knuiman, Council, and Reinfurt examined approximately 2,000 miles in Illinois and 1,000 miles in Utah of homogenous highway segments. Homogenous segments were defined as contiguous segments with no change in functional classification, rural/urban designation, predominant terrain type, annual average daily traffic (AADT), one- or two-way operation, and shoulder width and type (14). Multi-vehicle and head-on/sideswipe opposite direction crashes decreased with an increase in median width. Single vehicle crashes also decreased, but to a much smaller extent. Researchers felt that a minimum median width of 30 feet was necessary to have an effect on crash rates and that any reduction in width beyond 30 feet would be marked by a decrease in safety (14). Similar to findings by Garner and Deen, Knuiman et al. found the most significant benefit of increased median widths in the overall crash rates. Drivers used the available median as a refuge to avoid a crash in their own travel lane. The overall crash rate reduction due to increasing median width continued until a width of approximately 60 to 80 feet, at which point no improvement in safety was realized (14).

Research was performed at the University of Wisconsin - Madison to study the relationship between median width and cross slope and determine the effect it has on roadway safety. Macedo examined median related crashes from 1988 to 1997 for Interstates 43, 90, 94, and U.S. Highways 41, 51, 53 in the state of Wisconsin. The investigation revealed 1,272 single vehicle crashes (SVA) and 341 cross-median crashes (CMA). A SVA was defined as a crash in which a vehicle entered and overturned in the median without striking another object, while a CMA was defined as a crash in which a vehicle crossed the median into the opposing roadway, whether or not they hit another vehicle (15). The majority of crashes discovered, approximately 91 percent, occurred on highways with median widths of 60 feet or greater. Macedo attributes this to the fact that median widths of 60 feet or greater represent 73 percent of all the highway miles examined while only 27 percent of the highway miles examined had narrow median widths, and the fact that a large portion of the narrow median roads have median barriers. Macedo completed statistical probability models for varying cross slopes to determine the likelihood of a CMA at a given median width. Presented in Figure 11, the models show a steady decline in CMA probability as median width increases. However, even at a median width of 85 feet, the probability of a CMA is still 10 percent (15).

For medians with a width less than 50 feet, Macedo suggests a steep slope, i.e., allowing the median to act like barrier. This premise was based on the theory that a vehicle overturn crash is a more favorable outcome than hitting a barrier or crossing the median into opposing traffic (15). Not all researchers and state officials agreed with this logic.

Table 3 presents injury data which substantiates the claim that a SVA is more desirable than a CMA. Macedo recommended a cross slope of 4:1 for median widths between 50 feet and 75 feet; slopes up to 6:1 were considered acceptable. For medians that are wider than 75 feet, the research indicated that a flat, traversable median did not show an increase in cross-median crashes. For this reason, and to prevent overturning vehicles in the median, flatter median slopes were recommended (15). Figure 12 illustrates Macedo's findings.

Macedo plotted the 1,613 selected crashes by median width and median cross slope. As displayed in Figure 13, the crashes were fairly well distributed. There are also numerous CMA that occurred at median widths of 70 feet, 80 feet, and beyond. The data indicates that existing median width standards regarding the necessity of a barrier still allow for a significant amount of CMA.

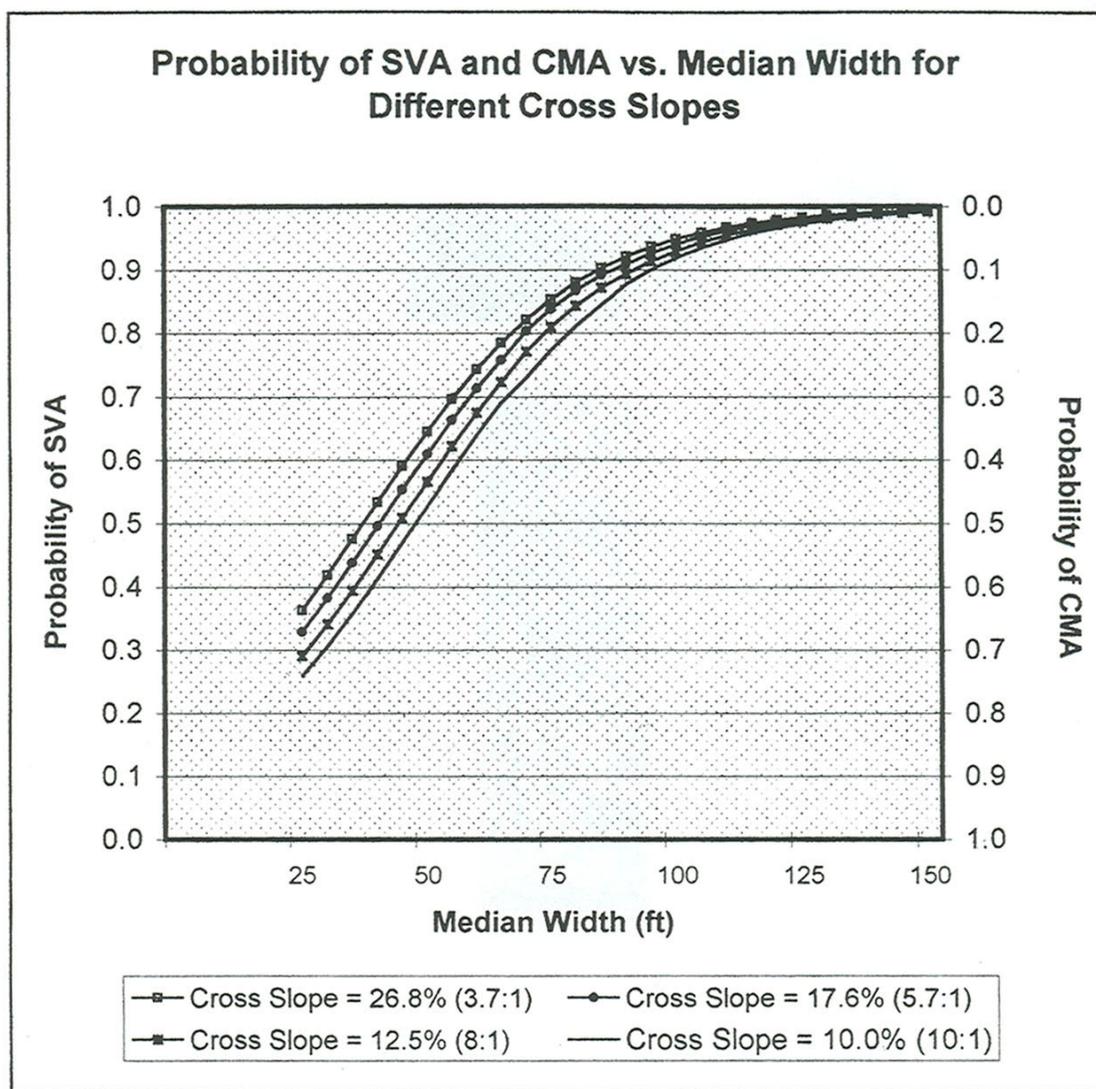


FIGURE 11 Probability of Single-Vehicle (SVA) and Cross-Median Accidents (CMA) versus Median Width for Different Cross Slopes (15).

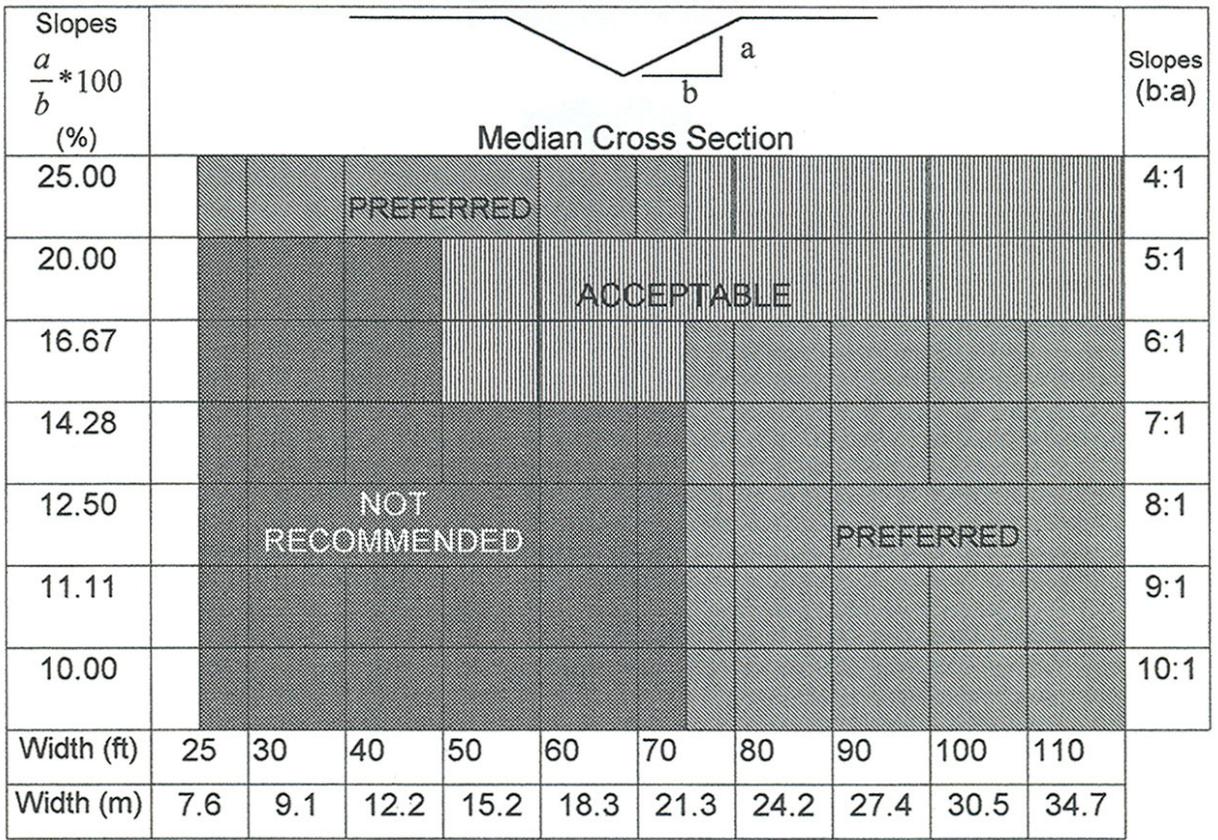


FIGURE 12 Recommended Combinations of Median Width and Cross Slopes (15).

TABLE 3 Proportions of CMA and SVA for Each Severity Class

Severity Class	Proportion of CMA (%)	Proportion of SVA (%)
Fatal (K)	5.87	1.10
Incapacitating (A)	18.18	8.88
Evident Injury (B)	20.23	20.20
Possible Injury (C)	12.61	15.80
Property Damage Only	43.11	54.01
Total	100.00	100.00

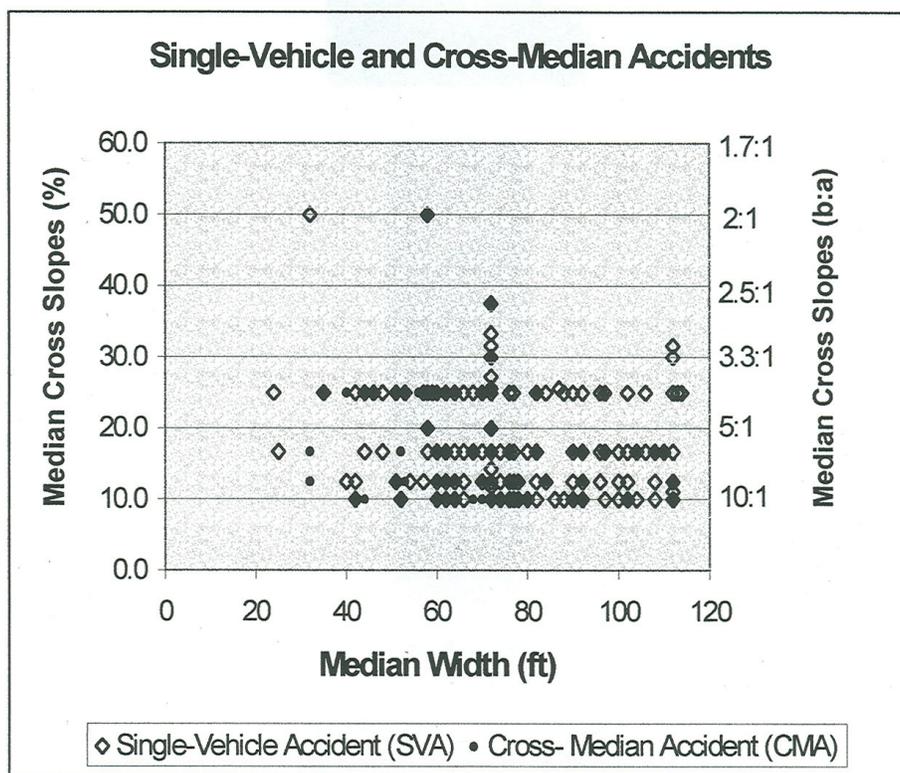


FIGURE 13 Single-Vehicle Crashes and Cross-Median Crashes for Different Median Cross Slopes (15).

Macedo examined the cost of each crash based on crash severity. Using the KABCO system of ranking crashes by injury severity, Macedo assigned a corresponding cost to each accident type. Costs were calculated using Federal Highway Administration (FHWA) data from 1994. Table 4 presents a cost breakdown for each of the five crash severities. Using the percentage that make up each crash, Macedo arrived at a weighted average cost for SVA and CMA crashes. Weighted cost averages are important, due to the fact that one fatal crash is significantly more costly than a large amount of property damage only (PDO) crashes. When examining the costs of a crash per mile per year versus the median width of a highway, wider medians were significantly lower in cost than narrow medians. Though all similar, steeper cross slopes, which are more difficult to traverse, had slightly lower costs than flatter medians. Figure 14 illustrates this point.

The literature presented shows the relationship between median width and the safety of a roadway. Garner and Dean and Knuiman et al. demonstrated that the presence of a traversable median that can be used as a place of refuge has a beneficial effect on all crashes for a road, not just crossover crashes. Garner and Dean further supported the need for a clear, traversable median by showing that raised or depressed medians led to an increase in vehicles that either lost control or rolled-over. Macedo concurred with Garner and Dean on the need for a clear median, if the width was large enough to prevent a crossover crash. For shorter median widths, she advised that a steep raised median was acceptable, citing that a single-vehicle rollover crash was favorable to a crossover crash. The next section will examine one state's comprehensive review of crossover crashes.

TABLE 4 Median Crash Weighted Average Cost

Severity Crash	Comprehensive Accident Cost (\$)	Proportion of Accidents	Weighted Cost (\$)
Fatal (K)	2,600,000	1.10	28,616
A	180,000	8.88	15,991
B	36,000	20.20	7,274
C	19,000	15.80	3,002
PDO	2,000	54.01	1,080
Weighted Average Accident Cost (\$)			55,963

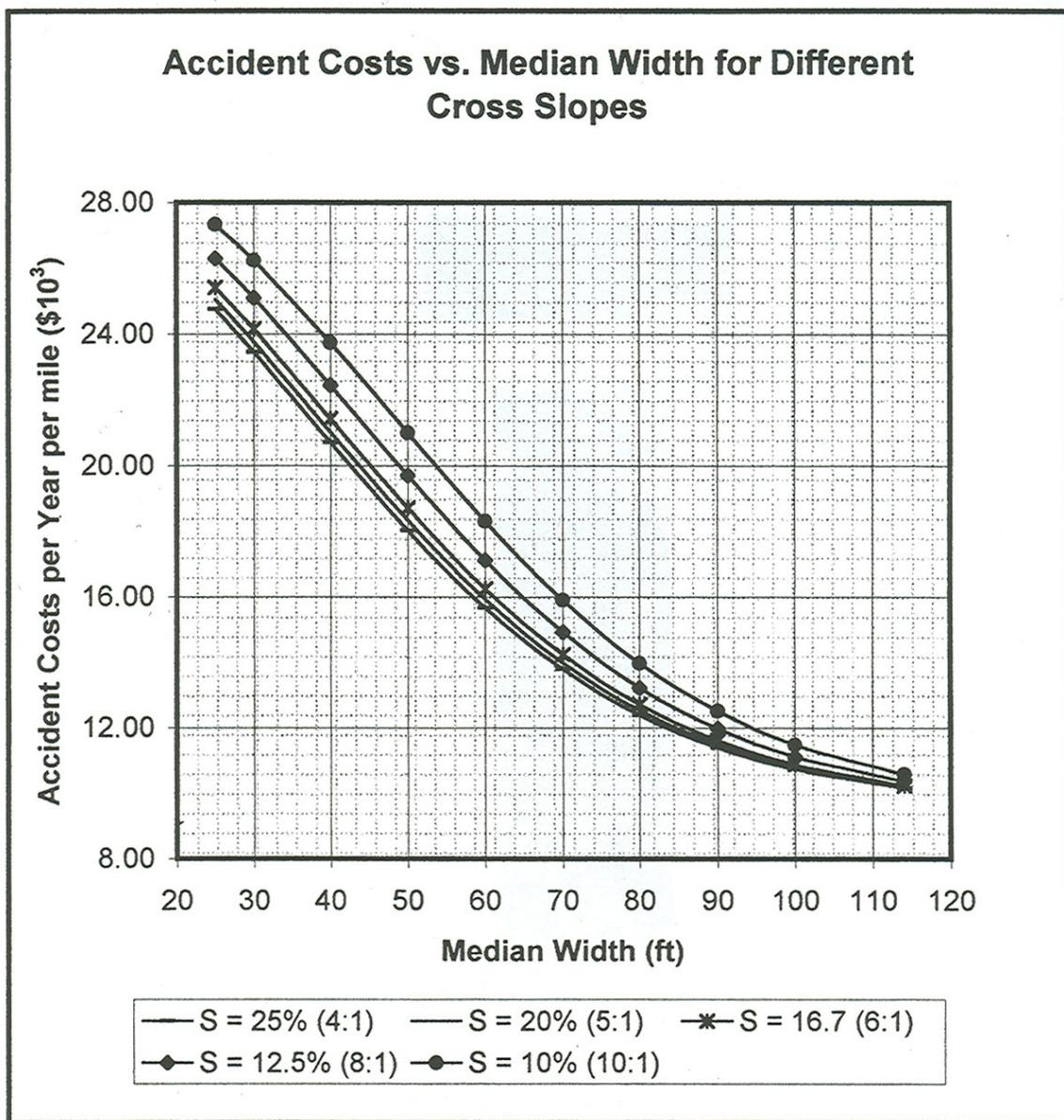


FIGURE 14 Accident Costs vs. Median Width for Varying Cross Slopes (15).

Median Crossover Crash Survey

The Pennsylvania Department of Transportation (PennDOT) undertook a comprehensive review of median crossover crashes in 2002. A panel of 23 transportation experts was assembled to assess their opinions on median crossover crashes. In the first analysis, experts gave their views on:

- The factors, other than ADT, median width, and accident history, that influence median safety on Interstates and expressways;
- The geometric and cross-sectional elements that can contribute to cross-median collisions;
- The accuracy of traversable and recoverable slope definitions;
- The significance of vehicle mix and operational characteristics on median safety;
- Tort liability information; and
- Median barrier type and placement guidelines.

In a second round, the experts were asked to rank their top four factors that would affect median safety from the 18 that were given in the preliminary analysis, and cite the most significant among the group. At the end of the process, the top four factors that would affect median safety, listed by the experts, were horizontal curvature, operating speed, median cross-slopes, and driver behavior (16). Among geometric cross-section features, inside shoulder width was selected as the mostly likely to affect whether a vehicle crosses the median. The panel made recommendations of three different types of median barriers depending on median width. For a width less than 20 feet, concrete safety barriers were advised. In the range for 20 to 33 feet, strong post W-beam guardrails were recommended. For medians greater than 33 feet, a three-strand cable barrier was the dominant choice. At median widths greater than 50 feet, the experts felt that it was at the discretion of officials as to whether a median barrier was warranted.

In addition to the opinions of experts, PennDOT did a review of crashes on Pennsylvania Interstates and expressways over the five year period from 1994 to 1998. A cross-median crash (CMC) was classified as one “in which a driver lost control of his or her vehicle, traversed the entire width of the median, entered the opposing roadway, and collided with a vehicle traveling on that opposing roadway” (16). Researchers discovered 267 crashes in this five year period that met the CMC definition. Their findings included:

- Number of vehicles:
 - 63% of CMCs were two vehicle crashes
 - 25% of CMCs were three vehicle crashes
- Reason for crash:
 - 71% of CMCs occurred when a driver lost control of the vehicle
 - 20% of CMCs occurred as a result of another same-direction vehicle collision
 - 8% of CMCs occurred as a result of a driver trying to avoid a same-direction vehicle
- Time of day
 - 63% of CMCs occurred during daylight (vs. 58% of all crashes)
 - 32% of CMCs occurred while dark (vs. 37% of all crashes)
 - 4% of CMCs occurred during dawn or dusk vs. (5% of all crashes)

- Weather
 - 43% of CMCs occurred under dry conditions vs. (61% of all crashes)
 - 32% of CMCs occurred under wet conditions vs. (19% of all crashes)
 - 25% of CMCs occurred under snow and ice conditions vs. (21% of all crashes)
- Under the Influence
 - 12% involved alcohol and/or drugs vs. (6% of total crashes)

Of the 267 CMC that PennDOT found, 216 occurred at sites that had earth-divided, traversable medians (16). These crashes were compared against median width and exposure, using units of crashes per hundred million vehicle miles traveled. Results indicated that as median width increased, adjusted for exposure (crashes per hundred million vehicle miles traveled (HMVMT)), crashes decreased. Table 5 presents these data.

TABLE 5 CMC Rate for Median Width Ranges On Earth Divided Medians

Median Width	Number of CMC Crashes	Exposure (HMVMT)	CMC Crash Rate (crashes per HMVMT)
<i>Interstate Highways</i>			
0-10	0	0.0	-
11-20	0	0.0	-
21-30	2	1.2	1.722
31-40	1	7.0	0.143
41-50	12	17.3	0.692
51-60	23	25.8	0.891
61-70	47	106.0	0.444
71-80	16	37.2	0.430
81-90	0	15.6	0.000
91-100	12	44.4	0.270
100+	5	43.7	0.114
<i>Expressways</i>			
0-10	10	4.3	2.336
11-20	4	3.5	1.130
21-30	12	12.5	0.959
31-40	19	23.6	0.804
41-50	22	19.1	1.151
51-60	16	28.6	0.560
61-70	5	15.3	0.326
71-80	2	9.1	0.206
81-90	0	3.3	0.000
91-100	5	10.2	0.490
100+	3	14.0	0.214

PennDOT made recommendations for several modifications to the crash form to make it easier to track median crossover crashes and their characteristics. A code to flag all median crashes was advised, which would include median crossover crashes, median barrier crashes, and crashes where a vehicle cleanly traversed the opposing direction (16). Additional data codes were recommended to distinguish between undivided versus divided highways, interchange locations, and access-controlled facilities versus non-access-controlled facilities.

The results documented in previous studies of median crossover crashes were consistent with the PennDOT results. The panel of experts convened by the state listed median cross-slopes as one of the four key factors in determining the likelihood of a crossover crash. The PennDOT crash survey augments the belief that driver behavior was a key factor in crossover crashes, with approximately 7 out of every 10 crossover crashes being attributed to a loss of vehicle control. The relationship between the crossover crash rate, adjusted for vehicle miles of travel (VMT), showed somewhat of a decrease in crossover crashes as median widths increased, but there wasn't a significant decrease in crash rates. In particular, the PennDOT data demonstrated that a median width of 60 feet, the standard in Wisconsin, still contained a high incidence of median crossover crashes. Also of note was the fact that a majority of the median crossover crashes found occurred on roadway segments with either lower traffic volumes or wider medians than what would warrant median barriers based on AASHTO guidelines (16).

Researchers for Auburn University and the FHWA examined the relationship between crash sites and median crossover crashes. Bowman, Paulk, and Zech conducted a review of median crossover crashes on non-Interstate divided partial access controlled arterials in the state of Alabama. Crash results indicated that a correlation could not be established between crash rates or crash frequency and site data. Researchers recommended that site specific crash experience was the best factor at identifying locations that should be investigated for median safety improvements (17).

Donnell and Hughes conducted a survey of state transportation agencies (STAs) to ascertain median design and safety practices. In research done at Pennsylvania State University, Donnell and Hughes received responses from 37 STAs regarding their median practices. Table 6 indicates mitigation measures that state agencies undertake in response to median-related crashes (18).

Nearly 70 percent of the responding STAs maintain data in reference to the causation of median-related crashes. Figure 15 indicates the six reported causes and how many state agencies reported a median-related crash due to each cause. Traveling too fast for conditions was by far the most reported cause; twice as many STAs responded with traveling too fast for conditions as a cause as did the second most reported cause, driver lost control (18).

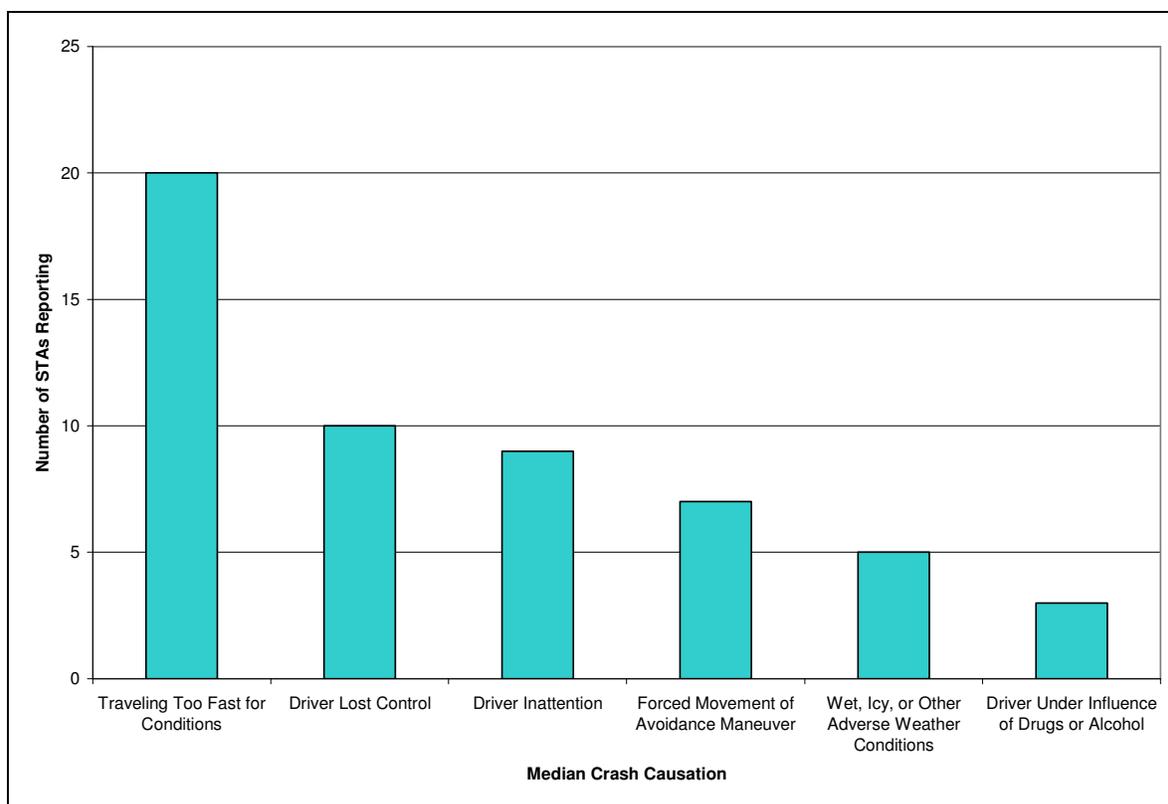


FIGURE 15 Median-Related Crash Causation.

TABLE 6 Median-Related Crash Mitigation Measures

Mitigation Measure	Number of STA Responses
Install median barrier	26
Flattening median side slopes	5
Install milled rumble-strips on left (median) shoulder	5
No known median-related crash problem, thus no mitigation measures	4
Check adequacy of geometric elements and consider safety improvements other than installation of median barrier (i.e. improved delineation, lower speed limit, etc.)	4

State Median Barrier Policy

AASHTO established guidelines for median barrier warrants in the *Roadside Design Guide* (19). Displayed in Figure 16, AASHTO shows only a need to evaluate the necessity of a median barrier at certain traffic volumes with a median width less than 30 feet; for median widths of 50 feet or greater median barriers are “not normally considered.” Wisconsin’s median barrier warrant criteria, also based on median width and ADT, is more conservative than what AASHTO recommends. As previously presented in Figure 9, Wisconsin warrants a median barrier for certain ADTs up to a median width of 60 feet.

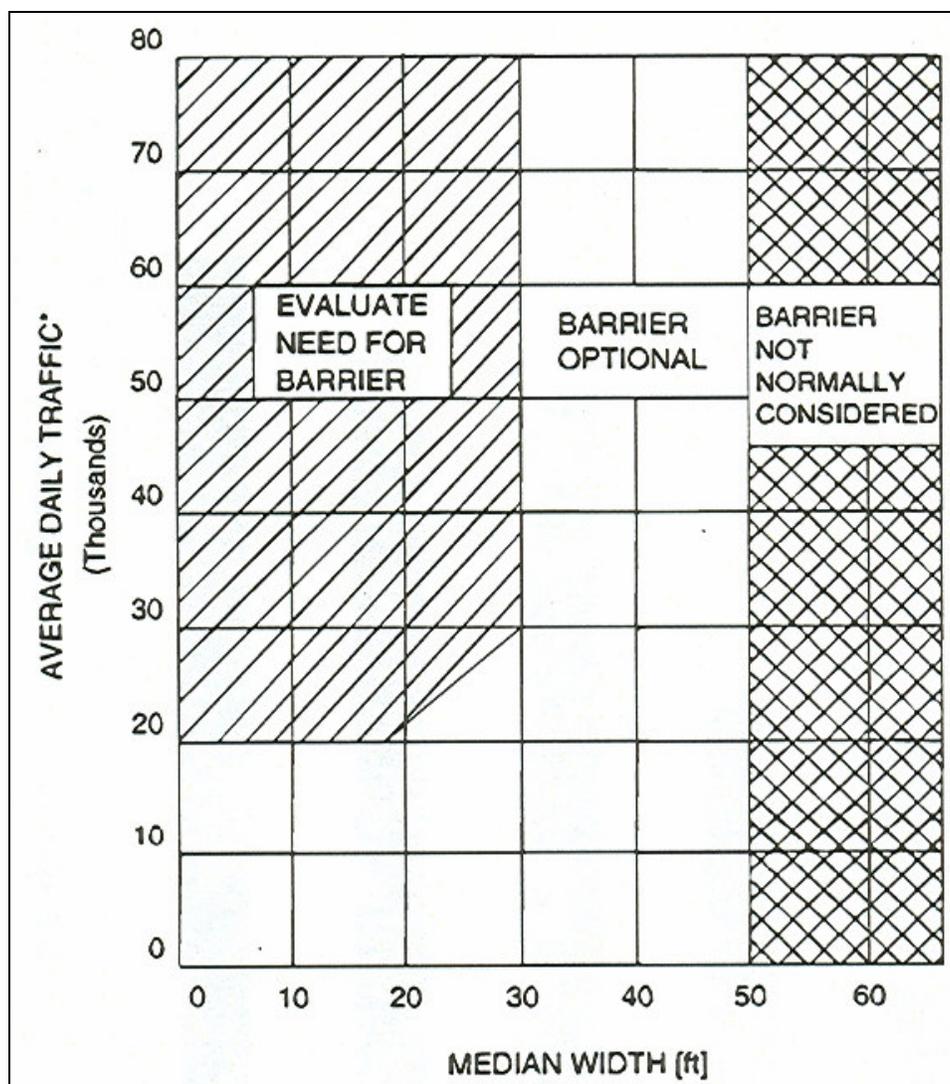


FIGURE 16 AASHTO Median Barrier Warrant Guidelines (19).

In 1995, for National Cooperative Highway Research Project (NCHRP) 375, a review of state highway agencies was conducted to determine a range of minimum, desirable, and maximum median widths for urban and rural divided roadways. As presented in Table 7, a variety of ranges exists, with a desirable median width of 54 feet as the average among the agency responses (20). In spite of the wide range of values, the data are similar to the AASHTO recommendations.

TABLE 7 Highway Agency Survey on Rural and Urban Highway Median Width

Median Width	Rural		Urban	
	Range (ft)	Median Value (ft)	Range (ft)	Median Value (ft)
Minimum	3 – 64	27	1 – 30	10
Desirable	5 – 26	54	9 – 64	30
Maximum	8 – 92	94	16 – 101	43

More recently, some states have chosen to be more stringent in their median barrier requirements. States such as South Carolina, Connecticut, North Carolina, Washington, and California have begun to implement varying median barriers in medians that were not previously deemed barrier-necessary. The drop in median crossover crashes and fatalities since the installation of the median barriers has been noticeable and significant.

In South Carolina, median crossover fatalities dropped from over 70 fatalities during the two-year period of 1999 to 2000, to only 8 fatalities during the three years after the installation of cable guard median barrier on all freeway sections with a median width less than 60 feet (21). Overall Interstate freeway fatalities fell by 36 percent over a two-year period during the implementation of the cable guard (21). Only after the installation of the cable guard did officials realize the true scope of problem; the median barrier system averages three hits per mile per year (21). Repair costs for the cable barrier average approximately \$1,000 per hit. In spite of this many hits, only 15 vehicles made it through or over the barrier during the three year analysis period (21).

According to the Connecticut Highway Design Manual, median barriers are warranted for all freeway median widths up to 66 feet and on wider medians if crash history indicates a need (22). The inclusion of crash history as a warrant for median barrier installation is important because it points out the fact that certain sites, in spite of meeting established design criteria, may still need median safety improvements. Connecticut regulations also indicate that in sections where median width varies, the median barrier should extend for 100 feet into the section where width no longer requires a barrier (22).

North Carolina recently completed a five year project of implementing cable guard median barrier for all freeway sections with a median width less than 70 feet (23). Between 1999 and 2004, over 1,000 miles of freeway had cable guard installed, resulting in an average of 25 to 30 lives saved per year plus an estimated 90 percent reduction in the amount of crossover crashes (23). The installation of the cable barriers cost \$55,000 per mile including labor and materials costs. However, the 96 lives the barrier has saved has resulted in a savings of more than \$290 million in crash costs, following NHTSA's estimate of approximately \$3 million per fatality (24).

Washington State has installed cable median barrier at approximately 25 miles of test sites on Interstate 5 with median widths of 40 feet, 48 feet, and 48 to 82 feet (25). The annual crash rate for the experimental sites for all median crossover crashes decreased from 16 crashes per year before installation to 3.83 crashes per year afterwards. The rate of disabling and fatal crashes decreased from 3.8 crashes per year to 0.33 crashes per year, with no fatal crashes to date since the installation of the cable median barrier (25). Installation of the cable barrier cost \$44,000 per mile with an annual maintenance cost of \$2,570 per mile. Though the overall rate for all median crashes doubled, from 49 crashes per year before installation to 100 crashes per year afterwards, the decrease in fatal and disabling injury crashes was found to have resulted in a net benefit to society of \$420,000 annually per mile (25). Cable median barrier was the most cost effective, with a benefit cost ratio ranging from 2.7 to 5.5 for median widths up to 50 feet. However, both beam guardrail and concrete median barriers, in addition to cable median barriers, were all found to be cost effective for median widths up to 50 feet (17).

The Florida Department of Transportation (FDOT) requires median barriers be installed on all highways with a median width less than 64 feet. FDOT conducted a five year review of median crossover crashes from 1995 to 1999. Among the results that were found (18):

- Approximately 19 percent of crashes involved or were suspected to involve alcohol;
- Approximately 2 percent involved a truck as the crossing vehicle;
- Approximately 78 percent of crashes occurred when the crossing vehicle's speed was within 5 mph of the posted speed limit;
- Weather conditions were good in roughly 75 percent of the crashes, with 83 percent of these crashes being the result of driver error and avoidance maneuvers;
- Roughly half the adverse weather crashes involved hydroplaning while the other half resulted from driver error and avoidance maneuvers; and
- Approximately 62 percent of all median crossover crashes occurred within one-half mile of interchange ramp termini, and approximately 82 percent occurred within one mile of ramp termini.

The Maryland State Highway Administration follows similar criteria to the State of Wisconsin, determining the necessity of a median barrier based on median width and ADT. In 2003, Maryland revised its guidelines for median barriers on high speed highways, defined as highways with a design speed greater than 45 mph (18). Median widths up to 30 feet require a median barrier for all traffic volumes. As shown in Figure 9, Wisconsin does not require a median barrier under these circumstances. Median widths up to 50 feet with an ADT of at least 40,000 vpd also require a median barrier in Maryland. This standard is similar to the Wisconsin standard of median widths up to 45 feet with an ADT of at least 40,000. Median barriers are required for median widths up to 75 feet with traffic volumes greater than 80,000 ADT. This standard is more stringent than Wisconsin standards, which does not require median barriers for medians with widths greater than 60 feet (18).

California revised its traffic manual in 1998 with updated standards on when median barriers were appropriate. Similar to Wisconsin, a relationship between ADT and median width is one of the primary criteria in determining the need for a median barrier. Figure 17 shows the appropriate median width and ADT combinations that warrant a study to determine if a median barrier is required. In California, like Connecticut, the crash history of a site is also an important factor in deciding whether a median barrier is necessary. California Department of Transportation (CalTrans) indicates that if there are 0.5 median crossover crashes per mile per year, or 0.12 fatal median crossover crashes per mile per year, there is justification to study the feasibility of installing a median barrier (26). CalTrans recommended that the rate be determined based on at least three crashes over a five year period. Though standards for freeways, they may also be usable for other multi-lane roads (26). Guidelines indicate that concrete median barrier be used for medians up to 36 feet wide, though three-beam guardrail is acceptable for median widths of 20 feet to 36 feet if flooding or other circumstances exist (17).

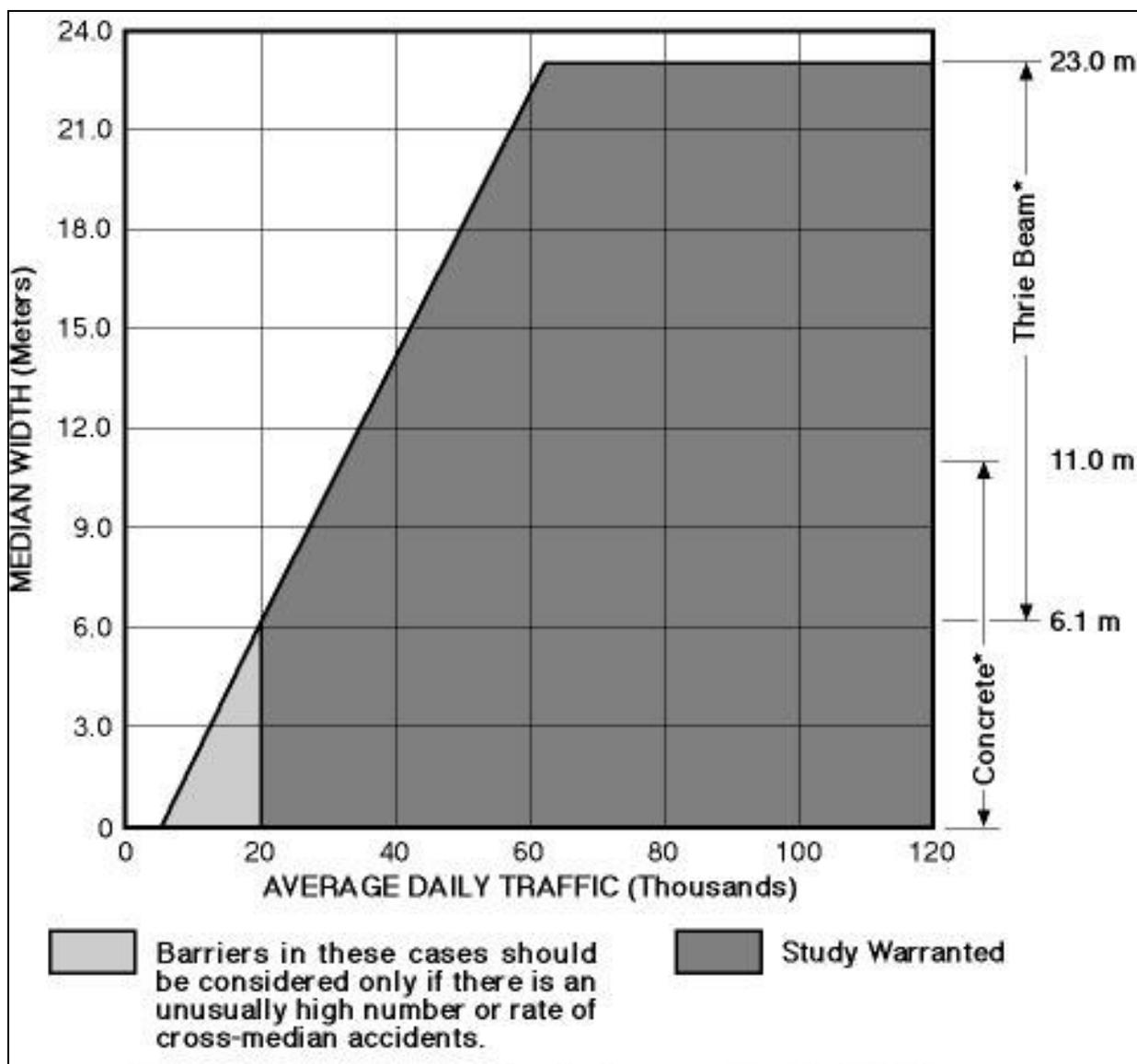


FIGURE 17 CalTrans Median Barrier Warrant Guidelines (26).

Types of Median Barriers

A variety of devices are available and used as median barriers. Median barriers are commonly grouped into three main categories: rigid, semi-rigid, and flexible. Presented are a brief description of each, their appropriate uses, and comparative costs.

Rigid Barriers

Concrete barriers are the most rigid type of median barrier. Commonly referred to as Jersey barriers, due to the shape developed and used by the New Jersey Turnpike Authority (NJTPA), concrete barriers have the purpose of minimizing the severity of a crash upon collision. The base of the barrier is a shallow slope to minimize sheet metal damage to a vehicle and to allow a driver the chance to regain control. If the barrier is hit higher up by a vehicle, it is designed to maximize the ability of a driver to regain control of their vehicle and recover cleanly onto the

roadway, attempting to avoid any yaw or pitch in the wheels that could cause a rollover (27). Figure 18 displays a typical concrete barrier design (7).

Concrete barriers are designed to have a vehicle's wheels ride up along the barrier. Concrete barriers should be placed on a paved surface to prevent the wheels of a vehicle from digging into natural earth surfaces underneath the barrier and thus increasing the likelihood of a rollover (27). For these reasons, in addition to their minimal lateral displacement upon impact, concrete barriers are often recommended for narrow median widths, often found in urban areas or corridors with minimal right of way. Figure 19 illustrates typical concrete barrier usage where median width is minimal.

Concrete barriers are the most costly type of median barrier. Cost estimates to install a concrete barrier range from approximately \$130,000 to \$1.4 million per mile for materials and labor, depending on the associated earthwork and/or paving needed (21, 26).

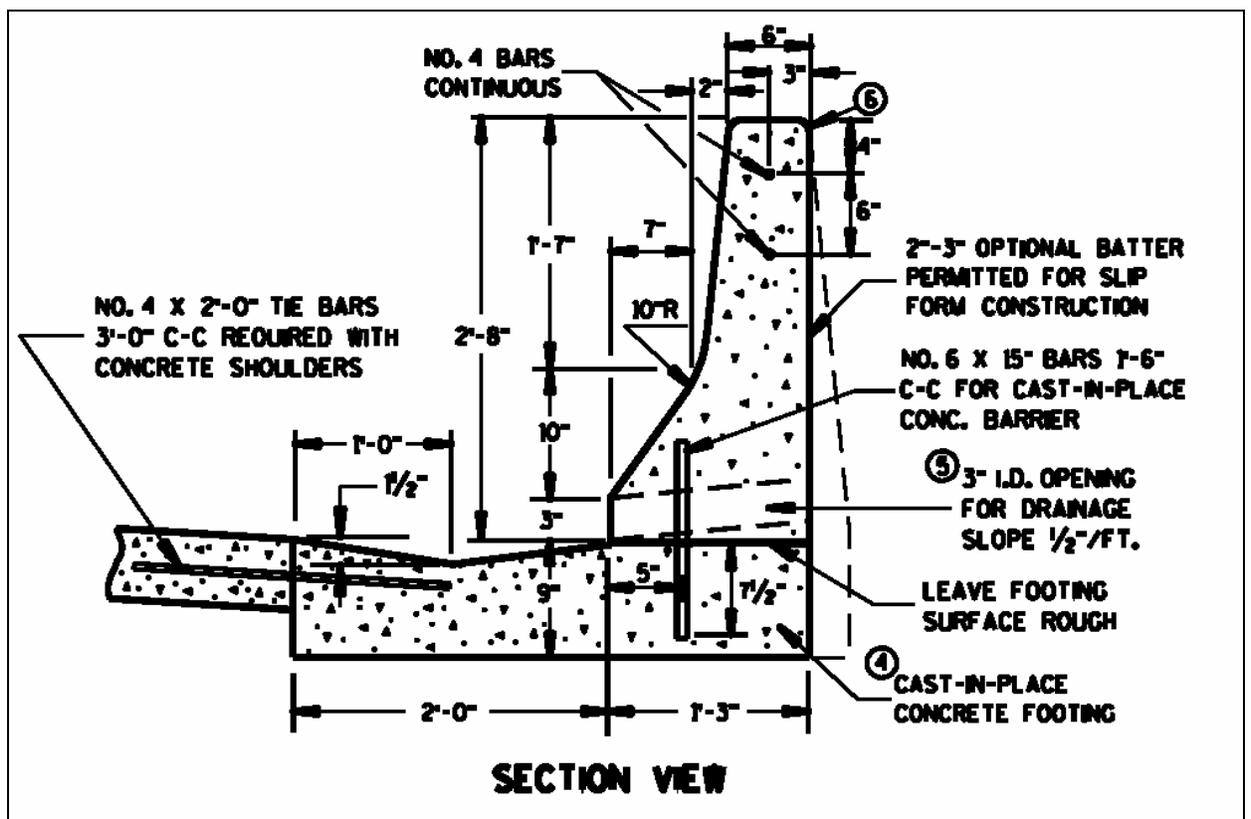


FIGURE 18 Typical Concrete Barrier Profile (7).

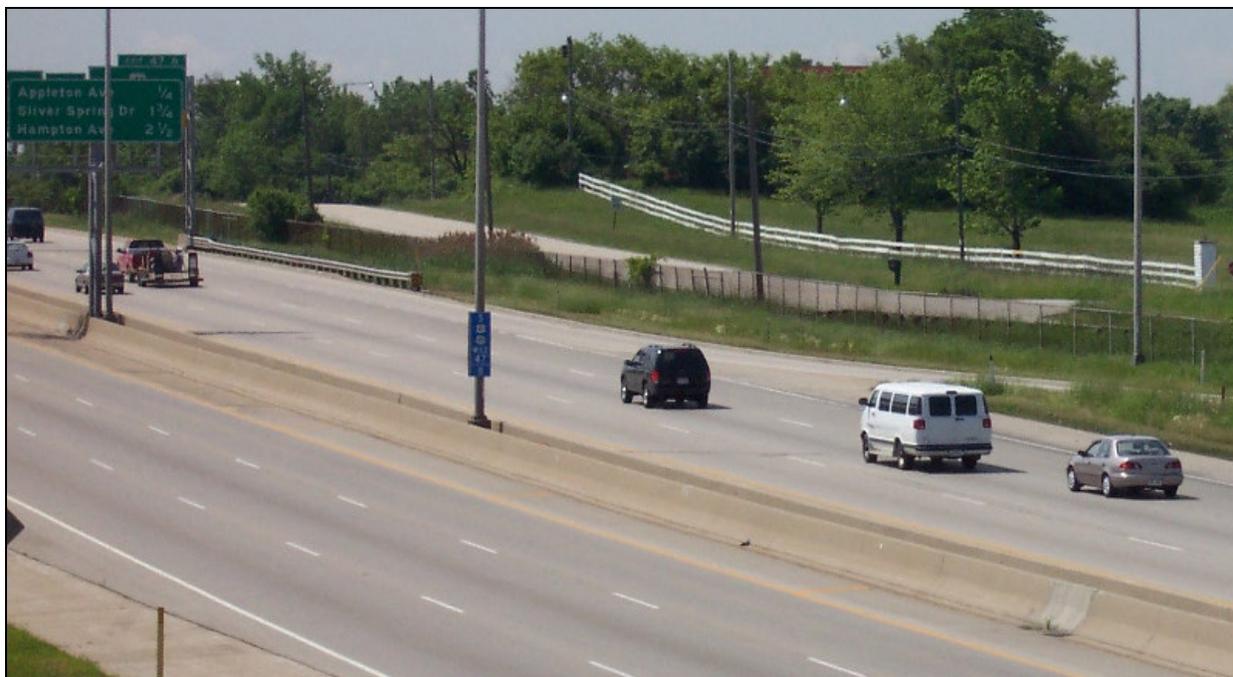


FIGURE 19 Typical Concrete Barrier on a Narrow Median Highway.

Semi-Rigid Barriers

Semi-rigid barriers are most commonly referred to as guardrail. Typically, guardrail consists of connected segments of metal rail supported by heavy posts and blocks. Support posts are made of either steel or metal, and usually placed 6 feet - 3 inches apart from each other (29). There are two common types of metal rail: W-Beam and Thrie-Beam, each named for the shape the rail takes. Illustrated in Figures 20 and 21, a W-Beam guardrail contains two protrusions in the rail while a Thrie-Beam guardrail contains three protrusions (30). The main difference in the two beams is size: the W-Beam is typically approximately 12 inches wide, while the Thrie-Beam is typically 20 inches wide (28). The added width of the Thrie-Beam makes it a better choice for areas with a narrower median where a more rigid barrier is required and at connection points to rigid barriers.

The installation cost of guardrail makes it more cost effective than concrete barrier. Some estimates have the cost of installation of a W-Beam, guardrail at \$72,000 per mile, though costs can vary widely (28). W-Beam and Thrie-Beam guardrail are classified as semi-rigid barriers, so they are able to be used under a variety of conditions. They are appropriate for a variety of surface conditions including natural earth. For narrow medians, it may be necessary to double-stripe the guardrail, i.e., run two rails back-to-back of each other for increased strength. Figure 22 displays a typical double-stripe guardrail.

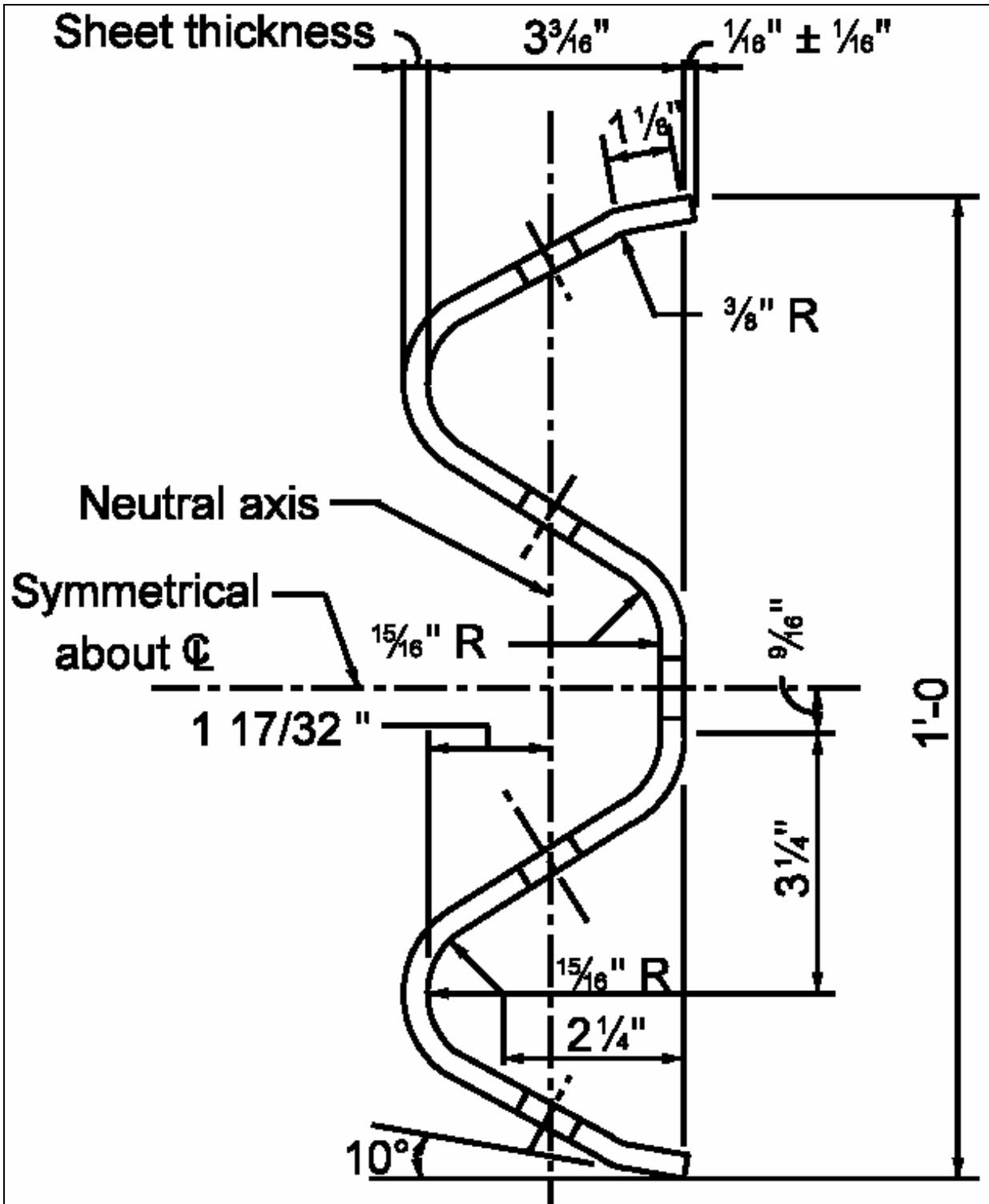


FIGURE 20 Typical W-Beam Guardrail Profile (30).

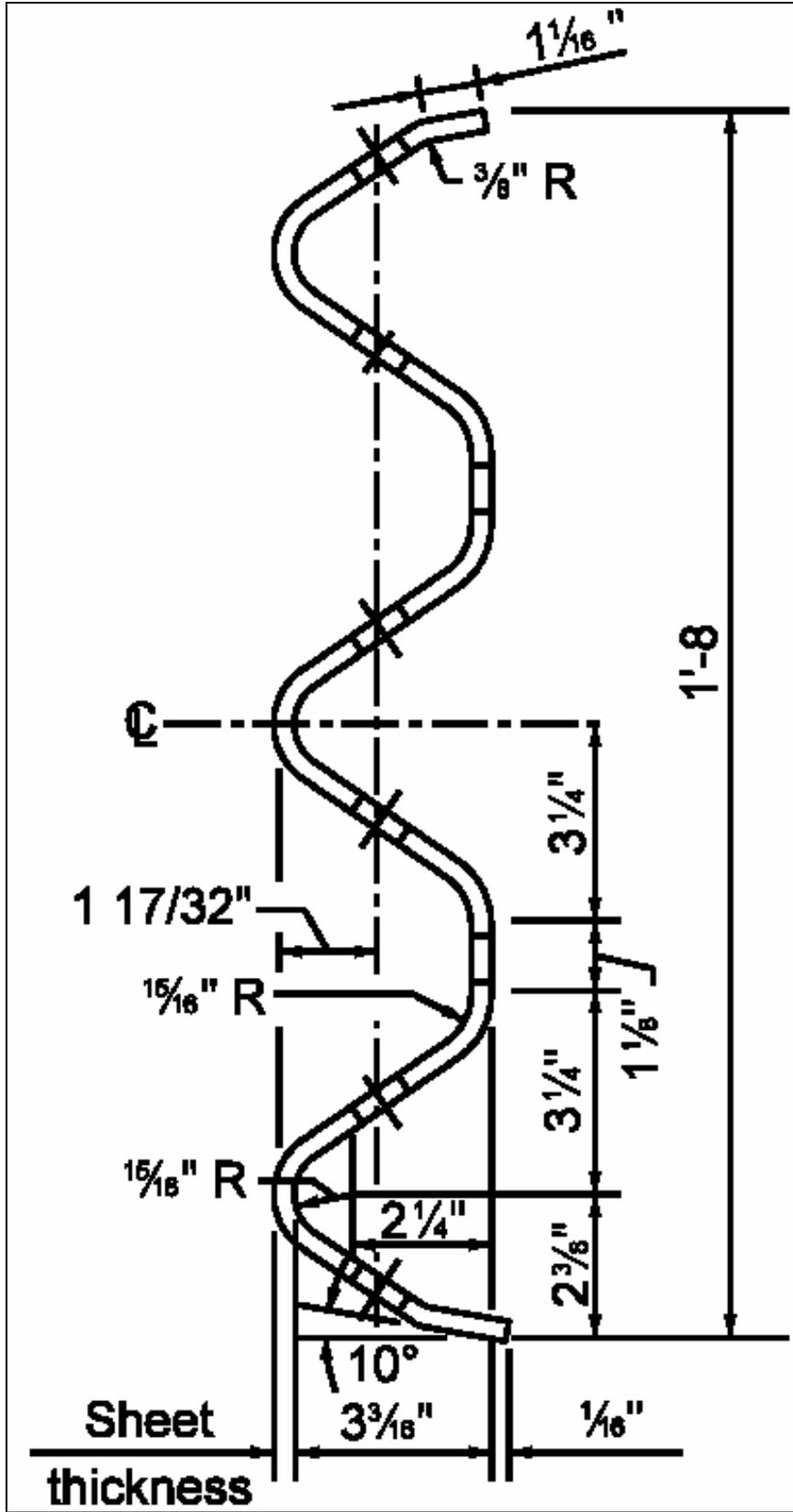


FIGURE 21 Typical Thrie-Beam Guardrail Profile (30).



FIGURE 22 Typical Semi-Rigid Double-Stripe W-Beam Guardrail on a Narrow Median Highway.

Flexible Barriers

Flexible barriers are commonly known as cable-barriers. The typical set up of a cable barrier is three steel cables that are connected to a series of posts. Figure 23 shows a diagram of a typical three-strand cable barrier, while Figure 24 illustrates their use in the field. Cable barriers are the easiest and most inexpensive barrier system to erect, requiring the least amount of time and labor. However, due to their design, cable barriers also require the most maintenance. Every time a cable barrier is struck by a vehicle, the cables may need to be reattached to the posts. Figure 25 shows workers for the South Carolina Department of Transportation repairing their cable barrier system.

Installation costs for cable barriers are the most inexpensive of any type of barrier. Costs estimates range from \$44,000 to \$55,000 per mile for materials and labor (21,26). Cable barriers are flexible, so they are not designed to be used on the narrowest medians. NCHRP Report 350 specifies that “because the amount a given installation can deflect without adverse consequences depends on site conditions, it is not feasible to establish limiting deflection values for crash tests,” of such barriers (31). Hence, it is up to each agency during their testing of barriers to “make an objective assessment of the appropriateness of the barrier for its intended application” (31). For standard cable barrier, requirements are commonly set to approximately 10 feet of deflection for a 60 mph crash (32). A survey in Ohio found that older, traditional three-cable barrier with post spacing of 16 feet, had a deflection of 11 feet 2 inches, which did not meet new standards, but was acceptable under previous NCHRP requirements (33). North Carolina Department of Transportation requirements for their cable barrier installation set post spacing to a maximum of 16.4 feet (23). Deflection requirements were unavailable.

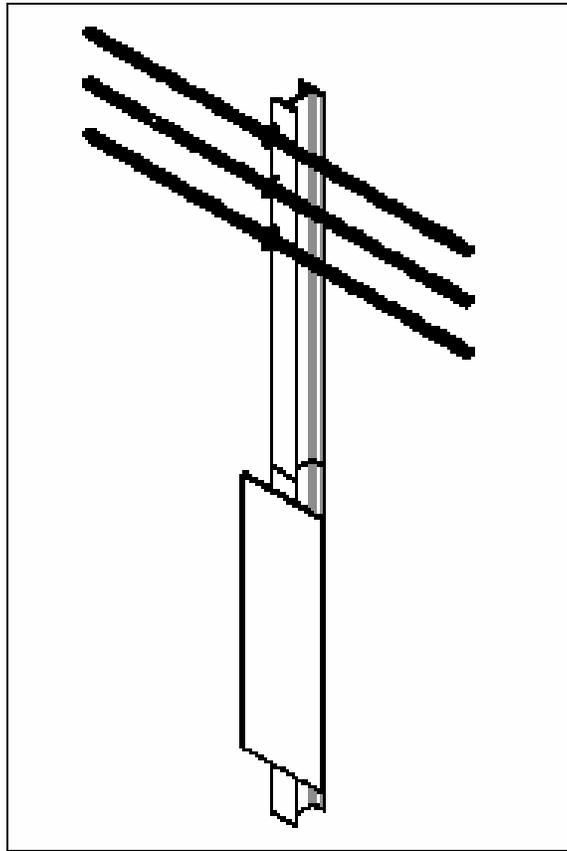


FIGURE 23 Typical Three-Strand Cable Barrier Profile.



FIGURE 24 Typical Three-Strand Cable Barrier on a Highway (23).



FIGURE 25 Cable Barrier Repair (21).

Flexible barriers are the most likely to cause the least amount of damage to a vehicle which makes them a popular choice. However, median widths must be of sufficient width to allow for the stretching of the cable to prevent a vehicle from crossing over. This has been previously mentioned in reference to the programs North Carolina and South Carolina have enacted to install cable barrier on all medians under a certain median width standard.

Motorcyclists have noted concerns about the use of cable median barriers. Motorcycle riders often raise concern about getting “sliced” by the cables of a flexible median barrier. Little research has been done in this area, as there are few documented cases of motorcyclist crashes with flexible median barriers. It is commonly cited, in response to motorcyclists’ arguments, that a collision with a semi-rigid beam guardrail, a concrete barrier, or a vehicle traveling on the opposing roadway, i.e., a crossover crash, would likely result in equal or more serious injuries than a crash with a flexible median barrier. A review of crash reports for approximately 375 miles of Swedish highway with flexible median barrier installed revealed no instances of a motorcyclist being injured by a flexible median barrier (34). Generally, very few motorcyclists are involved in median crashes (34). This is substantiated by the research results presented later in this report in which only one crossover crash involved a motorcycle crossing into the opposing direction of traffic.

Several proprietary types of cable barriers have been developed for median applications. Three of the most common include the Brifen Wire Rope Safety Fence (WRSF), the Trinity Cable Safety System (CASS), and the Marion Steel barrier (32). Each of these systems contains cables that are pre-tensioned, unlike traditional cable-barrier systems that are not tensioned. Table 8 contains a detailed review that was performed by the Ohio Department of Transportation (ODOT) on each of the three proprietary systems, along with traditional cable barrier (33).

Developed by a British company, and now marketed in a number of countries in the world including the United States, the Brifen WRSF is a four-strand cable design, as illustrated in Figure 26. Figure 27 displays a typical installation of the Brifen WRSF on a highway. The

Brifen WRSF is designed to absorb a large portion of the energy associated with a crash. At current installations, it has shown a remarkable ability to contain an errant vehicle, even a full sized loaded tractor-trailer truck, without having a cable break. Figures 28 and 29 display pictures from a truck crash on I-25 in Colorado (35).

TABLE 8 ODOT Cable Barrier Comparison (33)

	Brifen	Marion	Trinity	Base (generic)
Description	4 cable woven, tensioned and pre-stretched	3 cable tensioned but not pre-stretched	3 cable tensioned and pre-stretched	3 cable un-tensioned and not pre-stretched
Product History	3000 km of use 20 foreign countries	New system, based on well used frangible sign posts	New System to the USA, but modified from an existing European system	Generic Cable has been in use in the US since 1960s but not an ODOT standard
Segment Length	14 miles	12 miles	3 miles	12 miles
Post Spacing & Crash Deflection	10 feet 6 inch spacing 7.9 foot spacing	6 feet 6 inch spacing 6.5 foot spacing	10 foot spacing 7.9 foot spacing	16 foot spacing 11.2 foot spacing
Application	On one side of a median slope	At edge of wide paved shoulder on one side	At edge of wide paved shoulder on one side	On one side of median slope
Approx. No. Hits	160 (6.5 hits/mile/year)	30 (5.0 hits/mile/year)	10 (6.7 hits/mile/year)	n/a
Issues	One penetration of unknown reason has been recorded. Cable sagging in severe hits. District decision to replace driven posts with concrete socketed foundation affects timeliness of repair.	Replacing of problem anchor foundations. Retrofitting of the remaining anchor foundation to the Project Engineer's satisfaction. Redesign of damaged line post foundations. Keeping watch on the cable tension.	Anchor system is the same as on the Marion Steel system and may be vulnerable to movement as well.	D-12 Maintenance wrote in 2000 of the problems in maintaining the cable and keeping parts. D-12 then recommended replacing the cable with Type 5 guardrail.
Performance Conclusions	Performing to NCHRP Report 350 standards	Performing to NCHRP Report 350 standards	Performing to NCHRP Report 350 standards	Conforms to previous crash test criteria, NCHRP Report 230 standards
Summary	Best accident data, longest evaluation time, proven system elsewhere, extra cable woven. System seems to be proving itself beneficial	Construction issues, first substantial installation for product, so manufacturer's installation and repair manual being written after the fact from our experiences.	Construction went smoothly and observed repair was very easy. Looks to be a good system, but the length, and thus exposure to accidents is limited.	District says cable needs immediate attention after an accident and parts are difficult to obtain.

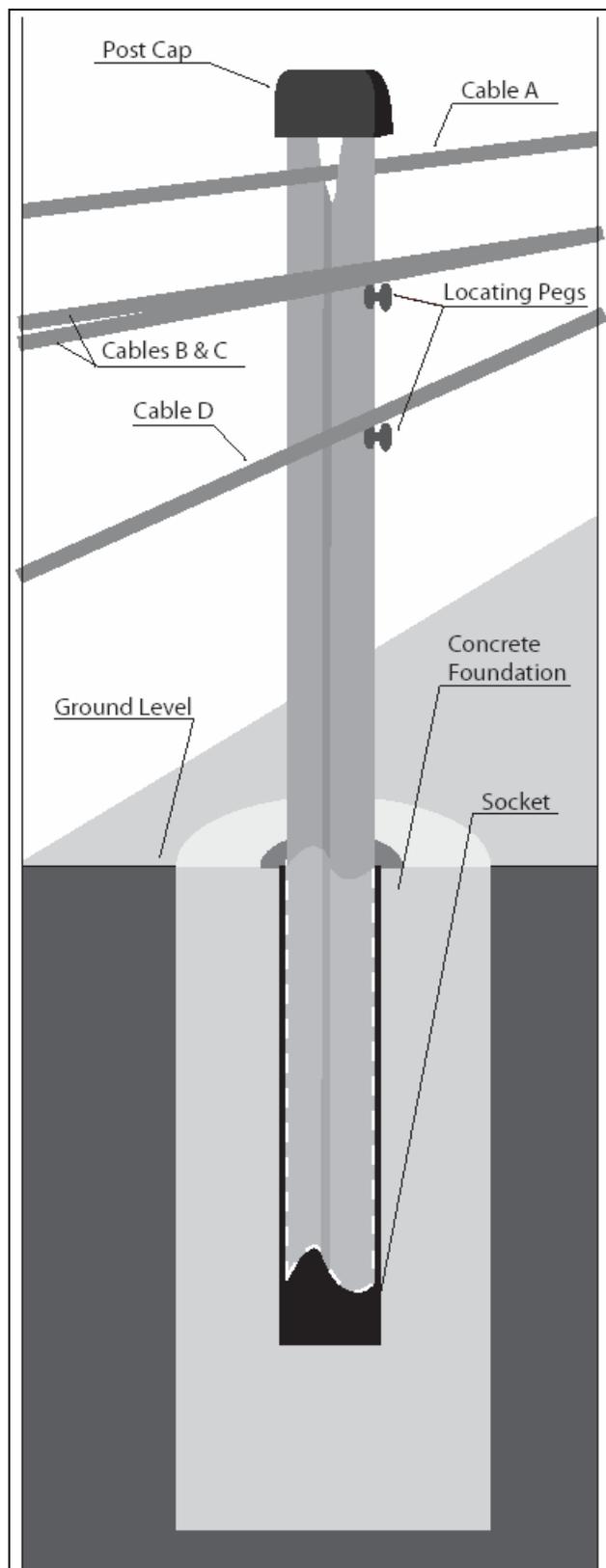


FIGURE 26 Brifen Wire Rope Safety Fence Profile.

(Source: http://www.ctre.iastate.edu/pubs/Tech_News/2004/mar-may/guardrail.pdf)



FIGURE 27 Typical Installation of the Brifen Wire Rope Safety Fence.
(Source: http://www.ctre.iastate.edu/pubs/Tech_News/2004/mar-may/guardrail.pdf)



FIGURE 28 Brifen WRSF Truck Crash on I-25 in CO (35).



FIGURE 29 Brifen WRSF Truck Crash on I-25 in CO (35).

The Brifen WRSF is somewhat more expensive than typical cable barrier systems, but still cost-effective when compared to concrete barriers or most higher-cost W-Beam guardrails. The installation in Colorado of the Brifen WRSF cost approximately \$65,000 to \$80,000 per mile (35).

Trinity Systems, Inc. of Dallas, TX has developed CASS, a three-cable high-tension barrier system. The CASS system is currently used less often than the Brifen WRSF, but has performed favorably. The Utah Department of Transportation (UDOT) has tested both systems with positive results. CASS has demonstrated its safety benefits by preventing more than one median crossover crash before being repaired; in fact, at one point the CASS was struck four different times before being repaired, with the cables preventing a median crossover crash in each instance (36). The CASS even prevented a median crossover crash during its installation, at a point prior to the ends of the cables being secured (36). CASS has the most cost effective system for maintenance and repair after collision.

The Marion Steel Company's SafeRoads system is the least known of these three proprietary systems. Based in Ohio, SafeRoads has been pilot tested on a 12 mile stretch of road by ODOT (33). The main difference between the Brifen WRSF and Trinity CASS is that Marion's SafeRoads is tensioned, but not pre-stretched. The majority of issues with SafeRoads have involved installation and repair, since ODOT is the first to use the system.

Donnell and Hughes, in their STA survey, discovered seven common median barrier types among the three categories describe above. Table 9 presents each barrier type, design deflection, applicable site conditions, and other information (18). Propriety cable barrier designs, such as the Brifen WRSF and Trinity CASS, are not included in this table. Figure 30 displays how many of the 37 STAs surveyed employ different median barriers, including three different shape concrete barriers and the Brifen WRSF (18).

TABLE 9 Median Barrier Types and Placement Recommendations

Barrier Type	Design Deflection	Recommended Site Conditions	Other Notes
<i>Flexible Median Barrier Systems</i>			
Weak-post, W-Beam	7 feet	Flat, traversable slopes	<ul style="list-style-type: none"> • Can remain effective after struck • Sensitive to mounting height • Requires proper end anchorage
Three-Strand Cable	12 feet	Flat, traversable slopes	<ul style="list-style-type: none"> • Inexpensive installation • Requires proper end anchorage • Ineffective after being struck • Expensive to maintain
<i>Semi-Rigid Median Barrier Systems</i>			
Box-Beam	5.5 feet	Flat, traversable slopes	<ul style="list-style-type: none"> • Posts designed to breakaway at impact • Posts must be repaired after being struck
Blocked-out W-Beam (strong post)	2 – 4 feet	Median width of 10 feet or greater	<ul style="list-style-type: none"> • Can remain effective after impact • May require rub-rail • Higher impact forces than flexible systems
Blocked-out Thrie Beam (strong post)	1 – 3 feet	Requires effective barrier height	<ul style="list-style-type: none"> • Can accommodate larger range of vehicles than W-Beam • No need for rub-rail • Higher impact forces than flexible systems
Modified Thrie-Beam	2 – 3 feet	Requires effective barrier height	<ul style="list-style-type: none"> • Can accommodate larger range of vehicles • Does not usually require immediate repair • Higher impact forces than flexible systems
<i>Rigid Median Barrier Systems</i>			
Concrete Median Barrier	0 feet	Use in narrow, symmetric medians	<ul style="list-style-type: none"> • Low life-cycle costs • Effective performance • Maintenance-free • High impact forces • High installation cost

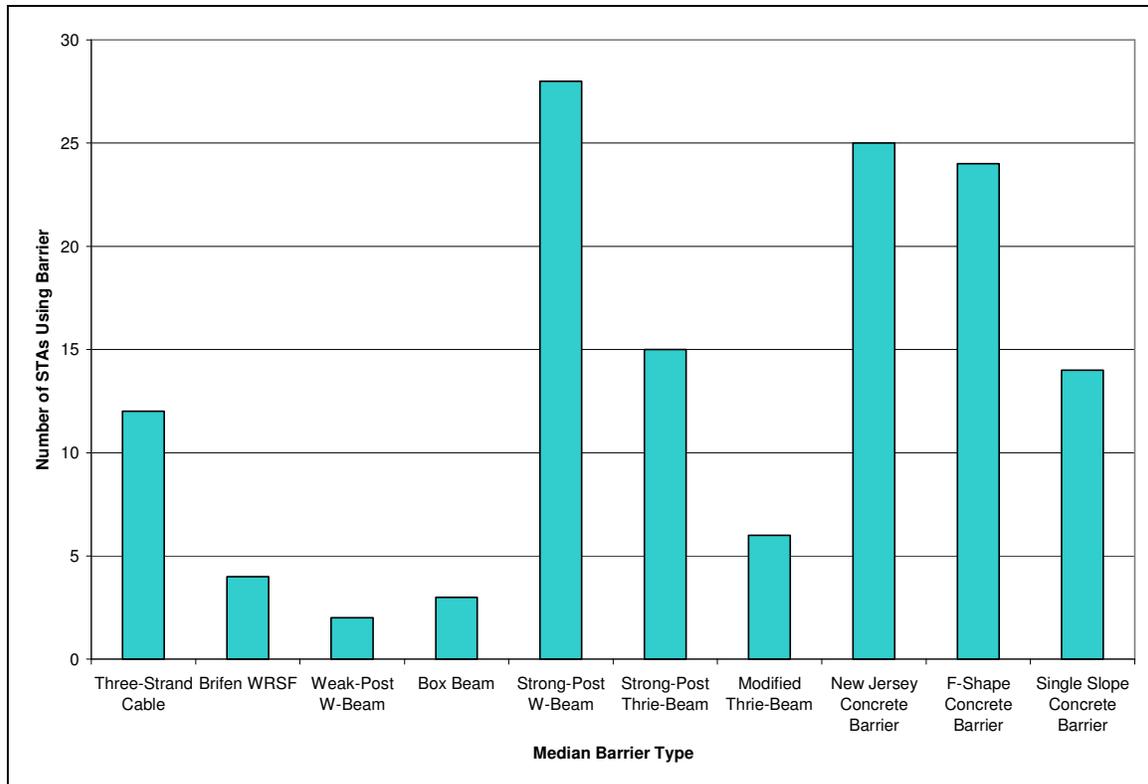


FIGURE 30 Median Barrier Use by State Transportation Agencies.

CHAPTER III STUDY DESIGN

To quantify the magnitude of median crossover crashes in Wisconsin, and to identify the causes of median crossover crashes, two hypotheses were developed along with five tasks designed to meet these objectives. This chapter presents these hypotheses and provides a thorough description of the research study design.

Research Hypothesis

Based on the literature review and objectives of the research, the following hypotheses were developed:

Hypothesis 1: There are a significant number of median crossover crashes in Wisconsin.

Hypothesis 2: There is a relationship between median width and the rate of median crossover crashes.

Research Tasks

To test these hypotheses, the following research tasks were developed.

Task 1: Literature Review

A comprehensive literature review was conducted to identify the effect medians have on safety and their relationship to median crossover crashes. Specifically, median width, slope, and cross-section were investigated. Previous studies relating median width and median crossover crashes were reviewed to help ascertain what standards have been established for median width. A review of state standards for median barrier warrants and their resulting effect on crossover crashes was completed. Also included was a review of typical median barriers. The literature review included various design manuals, journals, and other published and unpublished documentation. All elements of the literature review were presented in Chapter 2.

Task 2: Median crossover crash Survey

The Wisconsin Motor Vehicle Accident Report is a Scantron sheet to record crash information into a computer database. However, there is no entry space to signify whether the crash involved a vehicle crossing the median. Therefore, crashes that were identified as potential crossover crashes were selected for this analysis. The Wisconsin Department of Transportation (WisDOT) stores crash data on a mainframe computer accessed through Statistical Analysis Software (SAS) code. Copies of the actual crash reports, showing any diagrams or narrative provided by the reporting police office are stored on microfilm at their headquarters in Madison, WI.

Site Selection

With the assistance of WisDOT traffic engineering staff, Interstate, expressway, and freeway segments with a divided median were selected as examination sites from the state's roadway database. The roadways selected are presented in Table 10. Crash reports for the examination sites were gathered for the three most recent years of data, from 2001 to 2003.

TABLE 10 Wisconsin Roadways Reviewed for Crossover Crashes

Interstates	39, 43, 90, 94
U.S. Roadways	10, 12, 14, 18, 41, 51, 53, 141, 151
Wisconsin State Roadways	23, 29, 30, 35, 54, 57, 172, 441

Data Collection

The WisDOT crash database was initially queried at each of the selected roadway segments to identify potential median crossover and median entry crashes. The associated crash numbers produced a list of crash reports that were relevant to the research and required review of the actual crash report narrative and crash diagram. Each of the over 15,000 crash reports identified was reviewed on microfilm by a researcher to inspect whether or not the crash involved a vehicle that a) entered the median, and/or b) crossed the median. Determination of crashes was made by examining the narrative and pictorial representation written by the reporting police officer on the WMVAR. Data were collected and classified by county and then by highway number. Digital images of each selected median crossover or entry crash report were obtained and archived during the microfilm review process. After gathering the crashes records, median widths and ADTs for the crash sites were added to each crash report's data summary. Median widths were obtained from the Wisconsin State Trunk Highway Log. ADTs were obtained from the 2003 Wisconsin Highway Traffic Volume Data Book. To obtain the correct median width and ADT, each selected crash was located either through its WisDOT Reference Point (RP) number or crossroads reference. Several roadways and crash locations were verified through field visits.

Task 3: Data Analysis

The data analysis examined the crash data of the selected median crossover crashes found in the survey of crash data from 2001 to 2003. Basic statistical data were initially derived including the number of crashes by type, location, and frequency, by demographic variables and related variables in the data set, including weather and ADT. The following information was determined:

Median Width and Crossover Crash Rate Relationship

The median crossover crash rate was calculated as the number of crossover crashes for a given segment of highway adjusted for vehicle miles traveled. Highway segments were determined to be a length of a specific roadway within a county. Portions of a highway that were undivided or those that contained a median barrier were excluded from the total length of a segment.

Initial First Action

Each selected crash was reviewed to determine the initial first action which caused the crash. Crashes were grouped into six categories:

- *Lost Control on Dry Pavement:* Driver of vehicle lost control for a variety of different reasons, including: avoiding another vehicle, driver fell asleep, driver was distracted.
- *Lost Control Due to Weather:* Vehicle lost control directly due to snow, ice, sleet, or rain. These are separate from the general lost control category.
- *Vehicle Collision:* Vehicle that crossed over the median after making contact with another vehicle traveling in the same direction which produced the crossover action.

- *Barrier*: Vehicle first struck a barrier which caused a loss of control and the crossover action.
- *Signpost*: Vehicle first struck a signpost which caused a loss of control and the crossover action.
- *Other*: These crossover crashes could not be classified by the other five categories.

Median Crossover Extent

Each selected crash was reviewed to determine the extent of the median crossover action. Crashes were grouped into four categories:

- *Partial*: Vehicle crossed over the median and came to rest with some portion of the vehicle having made it onto the paved surface, including the interior shoulder.
- *Into*: Vehicle crossed over the median and came to rest within the paved surface of the opposite roadway.
- *Beyond*: Vehicle crossed over the median, the opposite roadway, and came to rest at a location beyond the exterior shoulder of the opposite roadway.
- *Object*: No vehicle crossed over the median, but an object, a trailer that detached from a passenger vehicle, crossed over to the opposite roadway.

Crashes involving vehicles that only entered the median without penetrating the opposing traffic lane were also identified on selected routes.

Crash Vehicle

Each selected crash was reviewed to determine the type of vehicle(s) involved in the crossover action and, if applicable, collision in the opposite roadway. Crashes were grouped into eight categories:

- *Passenger Car*: Passenger vehicle crossed over the median without striking another vehicle in the opposite roadway.
- *Truck*: Commercial truck crossed over the median without striking another vehicle in the opposite direction.
- *Passenger Car – Passenger Car*: Passenger vehicle crossed over the median and initially struck another passenger car in the opposite roadway.
- *Passenger Car – Truck*: Either a passenger vehicle crossed over the median and initially struck a commercial truck in the opposite roadway or a commercial truck crossed over the median and initially struck a passenger vehicle in the opposite roadway.
- *Truck – Truck*: Commercial truck crossed over the median and initially struck another commercial truck in the opposite roadway.
- *Motorcycle*: Motorcycle crossed over the median without striking another vehicle in the opposite roadway.
- *Trailer*: Trailer in tow detached from a passenger vehicle and crossed over the median without striking another vehicle in the opposite direction.
- *Trailer – Passenger Car*: Trailer in tow detached from a passenger vehicle and crossed over the median and initially struck a passenger vehicle in the opposite roadway.

Crash Severity

Each selected crash was classified using data from the WMVAR based on the severity of the crash. Crashes were grouped into three categories:

- *Fatal*: At least one person was killed in the crash.
- *Personal Injury*: At least one person sustained bodily injuries during the crash.
- *Property Damage Only*: No person was hurt in the crash.

Statistical Models of Variables

Discrete outcome multivariate analysis techniques were used to identify the key variables associated with median crossover crashes. Analysis was done to show both what factors were more likely to cause a median crossover crash as well as what factors were more likely to increase the severity of a median crossover crash. Logistic regression was used in the analysis to evaluate the discrete dependant variable of crashes. The significant factors affecting the causation of a median crossover crash were examined in relationship to the total amount of median crossover crashes to evaluate what settings to each variable were the most common.

To evaluate each variable's effect on the severity of a median crossover crash, the total crashes were divided into property damage only, personal injury, and fatal crashes. With three respective groups of crashes, relative ratio analysis was performed. Relative ratio analysis is the process by which the ratio of one variable is related to the ratio of another variable. Using the results of these analyses, predictive models can be developed to attempt to identify locations and conditions that are conducive to crossover crashes. An example of such a predictive model is the previously mentioned "0.5 crash per mile per year" or "0.12 fatalities per mile per year" warrant for determining the necessity of a median barrier. In this instance, previous crash history is used to predict the likelihood of future crashes.

Task 4: Benefit/Cost Analysis

CODES provided the cost data necessary to consider a benefit/cost analysis. An independent party at the Center for Health Systems Research and Analysis (CHSRA) at the University of Wisconsin-Madison was given the median crossover crash data to link with the CODES data. CODES data provides medical costs associated with each crash. CODES data were used to assess injuries and assign a financial cost for each crash. Costs of the selected crossover crashes were calculated and compared with the costs of crashes at similar locations that had a safety feature present, such as a median barrier. The difference in the costs of these crashes, along with the labor and maintenance costs of any safety improvements, was used to develop the basis for a benefit/costs analysis for proposed safety treatments for roadways. Because information related to median cross-section and cross-slopes was not available for each of the roadway segments selected, the cost of installing each median barrier type could not be determined and hence a full benefit/cost analysis could not be completed. Nevertheless, the key elements of benefits and costs were presented and discussed.

CHAPTER IV RESEARCH RESULTS

The objective of this research was to determine the magnitude of median crossover crashes in the state of Wisconsin. As previously stated in Chapter 3, the total number of median crossover crashes was calculated through an analysis of crash reports on Wisconsin highways for the period 2001 to 2003. In addition, the data from each selected median crossover crash were used to establish a relationship between median width and median crossover crashes as well as the causes and characteristics of median crossover crashes. This chapter documents the research findings.

The first section of this chapter provides a breakdown of all the selected median crossover crashes, including years, roads, and locations. The relationship between median width and median crossover crashes adjusted for VMT is then explained. Recall that to determine the probable cause of a crossover crash, one of six initial first actions (lost control on dry pavement, lost control due to weather, vehicle collision, collision with barrier, collision with signpost, other) were selected. The crash characteristics were analyzed to determine the significant factors affecting a crossover crash.

Crossover Crash Totals

A total of 15,194 crash reports were obtained from the WisDOT crash data archives for the period of 2001 to 2003, and reviewed/analyzed between May and September of 2004. The crashes reviewed were selected by the WisDOT traffic engineering staff and flagged as possible median crossover crashes. After completing the review and analysis, 732 median crossover crashes were initially identified. Each selected median crossover crash was re-examined to both determine the first action (potential cause) of the crash and to also confirm that each was an actual median crossover crash. A total of 101 crashes were disqualified from the selected crossover crash total during this process. Median crossover crashes involving objects, such as a tire, animal, crash debris, or person, were removed from the total as it was determined that standard median safety improvements, such as barriers, would not have prevented these objects from traveling airborne across the median. Tire crossovers compromised 52 of the 64 total object crossover crashes; the remaining 12 crashes were made up of a variety of objects, including debris, deer, and a person. Only crashes that occurred at a location without a median barrier were selected. Roadway segments with a median barrier installed were not included due to the fact that all roadway segments being examined were assumed to be classified as “non-barrier.” This criterion disqualified 32 crashes that involved a vehicle crossing the median in spite of a barrier; most of these vehicles vaulted or flipped over the barrier. An additional five crashes were removed due to the driver’s purposeful intent to cross the median. This re-examination modified the total number of crashes to 631 median crossover crashes. Table 11 breaks down the reductions taken to achieve the final median crossover crash total.

TABLE 11 Summary of Crossover Crash Total Calculations

Initial Selected Crossover Crashes	732
Object Crossover Crashes	-64
<i>Tire Crossover Crashes</i>	<i>(-52)</i>
<i>Other Object Crossover Crashes</i>	<i>(-12)</i>
Median Barrier Crossover Crashes (vehicle jumped existing barrier)	-32
Intentional Crossover Crashes (median u-turns or police evasion)	-5
Final Selected Crossover Crashes	631
Vehicle Crossover Crashes	624
Trailer Crossover Crashes	7

As presented in Table 10, segments of four interstates and 17 other Wisconsin highways were examined to quantify median crossover crashes. Table 12 shows the distribution of each of the three years evaluated, while Table 13 shows the breakdown of crashes selected for each roadway reviewed. In instances where two, or even three, highways run concurrently, the commonly referenced/coded highway was selected. The length of the highway is the total mileage of the divided highway without median barrier that was reviewed. A ratio of ‘median crossover crashes selected’ to ‘crashes reviewed’ was not possible due to the fact that not all reviewed crashes were median crossover crashes, i.e., some crashes occurred on highway ramps, and some involved vehicles at an at-grade intersection with a highway.

Median Crossover Crashes, Median Width, and ADT

The Wisconsin FDM guidelines for installation of median barriers use median width and ADT to determine if a median barrier is warranted. Recall from Chapter 1, Figure 9 that if a combination of median width and ADT intersected at the appropriate location in the figure, that a median barrier is warranted. To evaluate this relationship, the median width of each selected median crossover crash was plotted against the ADT of the crash. The median barrier standard from Figure 9 was then inserted into the plot to indicate which crashes occurred in areas that warrant a median barrier. Table 14 lists the total number of median crossover crashes by median width. Figure 31 displays the median width of each selected crash plotted against the ADT of the crash. Figure 32 also displays the median width and ADT of each crash, with the Wisconsin median barrier standard inserted. Of the 631 selected crashes, 514 median crossover crashes (81.5%) occurred at locations at which the Wisconsin FDM states that a median barrier is not warranted.

TABLE 12 Median Crossover Crashes by Year

Year	Median crossover crashes
2001	197
2002	229
2003	205
Total	631

TABLE 13 Selected Median Crossover Crashes by Highway

Highway	Counties	Median crossover crashes	Highway Length (miles)	Crashes/Year/Mile
I-39	Rock, Dane, Columbia, Marquette, Waushara, Portage, Marathon	107	182.38	0.196
I-43	Waukesha, Milwaukee, Ozaukee, Sheboygan, Manitowoc, Brown	44	148.86	0.0985
I-90	La Crosse, Monroe ¹ , Juneau ¹ , Sauk ¹ , Columbia ^{1,2} , Dane ² , Rock ²	19	45.27	0.140
I-94	St. Croix, Dunn, Eau Claire, Jackson, Monroe, Juneau, Sauk, Columbia ² , Dane ² , Jefferson, Waukesha	127	269.46	0.157
USH 10	Portage, Waupaca, Calumet	6	31.35	0.0638
USH 12	Dane, Walworth	16	40.54	0.132
USH 14	Dane ³	3	7.17	0.140
USH 18	Iowa, Dane ³	15	26.67	0.187
USH 41	Washington, Fond Du Lac, Winnebago, Outagamie, Brown, Oconto	112	136.54	0.273
USH 45	Washington ⁴	7	26.11	0.0894
USH 51	Dane, Columbia ² , Marquette ² , Waushara ² , Portage ² , Marathon ² , Lincoln	19	61.59	0.103
USH 53	La Crosse, Chippewa, Barron, Washburn, Douglas	35	149.37	0.0781
USH 141	Oconto	2	8.40	0.0794
USH 151	Grant, Iowa ⁵ , Dane ⁵ , Columbia, Dodge	41	99.75	0.137
STH 23	Sheboygan	1	12.73	0.0262
STH 29	Chippewa, Clark, Marathon, Shawano, Brown	64	183.46	0.116
STH 30	Dane	4	3.28	0.407
STH 35	St. Croix	2	8.36	0.0797
STH 54	Portage, Brown	1	16.77	0.0199
STH 57	Sheboygan	3	15.36	0.0651
STH 172	Brown	1	9.29	0.0359
	Total	631	1,482.71	0.142

¹Crashes on concurrent sections of I-90/I-94 were counted as part of I-94.

²Crashes on concurrent sections of I-39/I-90, I-39/I-90/I-94, and I-39/USH 151 were counted as part of I-39.

³Crashes on concurrent sections of USH 12/USH 14 and USH 12/USH 18 were counted as part of USH 12.

⁴Crashes on concurrent sections of USH 41/USH 45 were counted as part of USH 41.

⁵Crashes on concurrent sections of USH 18/USH 151 were counted as part of USH 18.

TABLE 14 Median Crossover Crashes and Median Width

Median Width (ft)	Median crossover crashes
< 30	13 (2.1%)
30 – 39	33 (5.2%)
40 – 49	34 (5.4%)
50 – 59	135 (21.4%)
60 – 69	348 (55.1%)
70 – 79	10 (1.6%)
80 +	58 (9.2%)

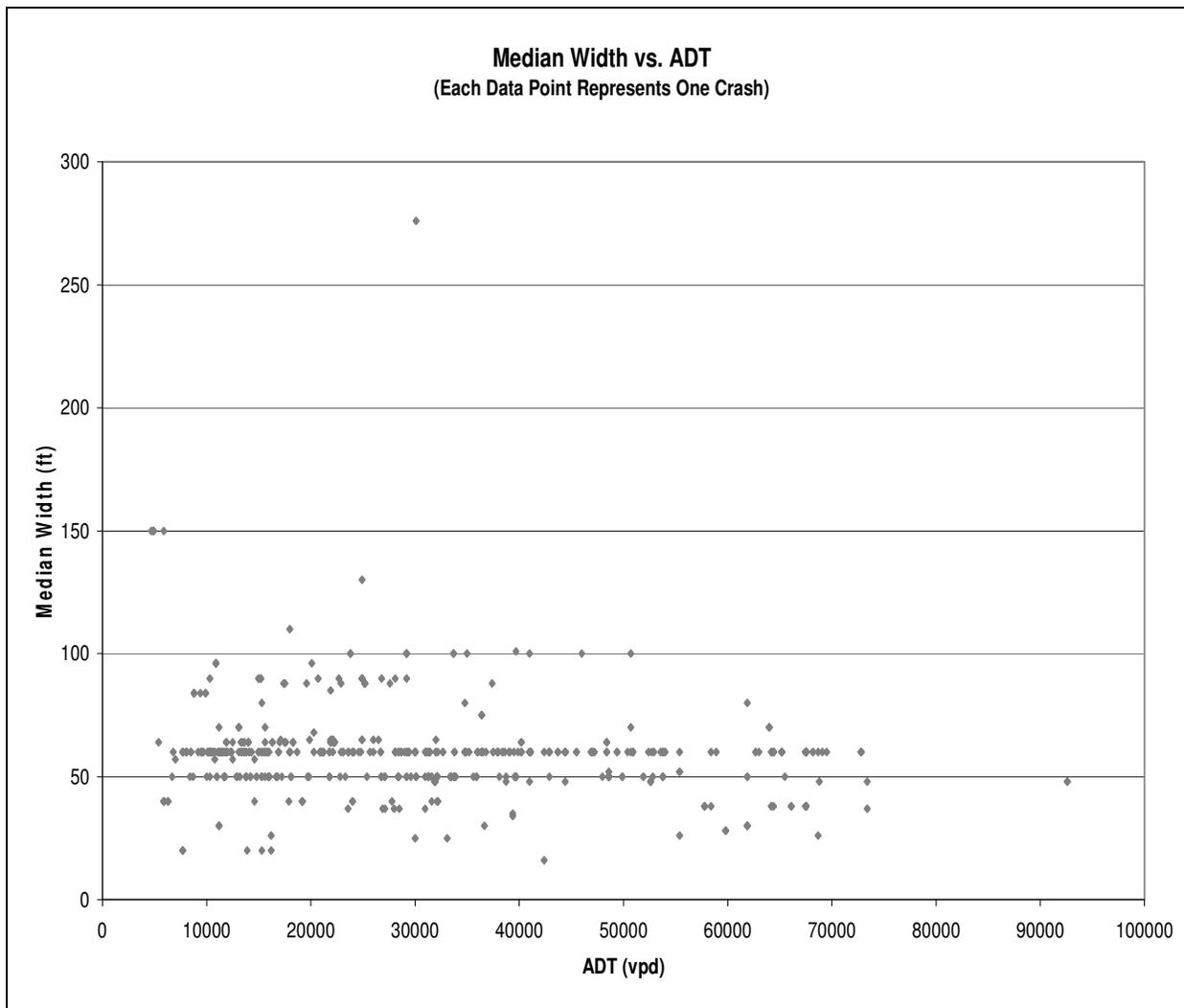


FIGURE 31 Median Crossover Crashes.

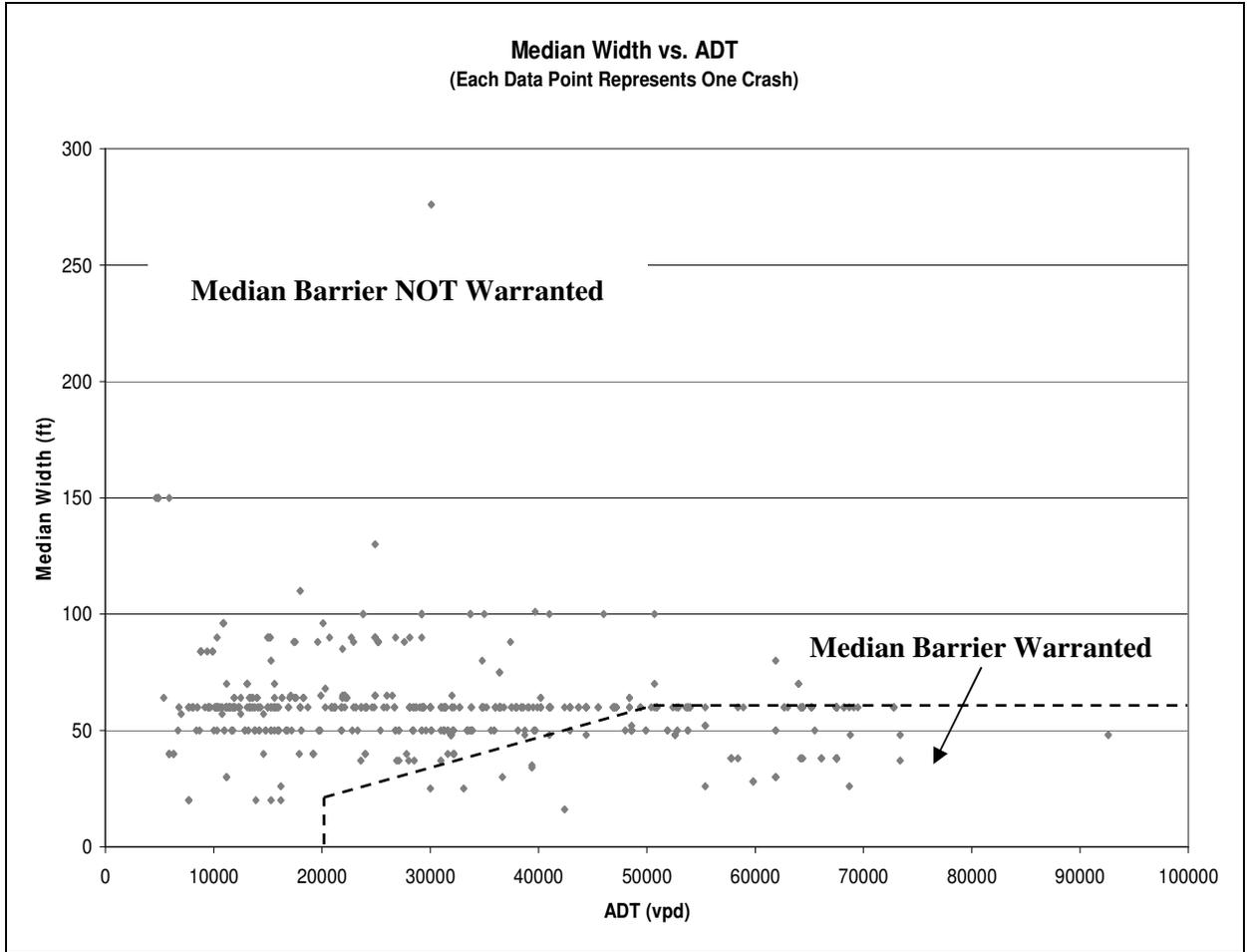


FIGURE 32 Median Crossover Crashes with the Wisconsin FDM Median Barrier Standard.

In an attempt to derive a median crossover crash rate, crashes were grouped together based on their location. Crash segments were created by grouping together the crashes for a particular highway within a particular county. The median crossover crashes for each segment were normalized by VMT to obtain a median crossover crash rate. The rates were plotted against the average median width for each segment. Figure 33 displays the 66 highway segment points and their average median width. There is some decrease in the median crossover crash rate as median widths increase, although the improvement is not significant given the low coefficient of determination (R^2) value of the least square line. Note that several highway segments exhibit noticeably high median crossover crash rates in spite of large median widths.

Crossover Crash Vehicles and Crash Severity

The number of vehicles involved in each selected crash was obtained from WisDOT data. Table 15 lists the total number of crashes by the total number of vehicles involved. In addition, the type of median crossover vehicle collision was obtained from a review of the selected crash reports. Crash vehicles were grouped into single vehicle type and multiple vehicle type median crossover crashes. Single vehicle type median crossover crashes, classified as passenger car, truck, or motorcycle, were defined as those in which the vehicle crossing over the median did not come in contact with a vehicle traveling on the opposite side of the roadway. Multiple vehicle type crossover crashes, classified as passenger car – passenger car, passenger car – truck, and truck – truck, were defined as those in which the vehicle crossing over the median made contact with a vehicle traveling on the opposite side of the roadway.

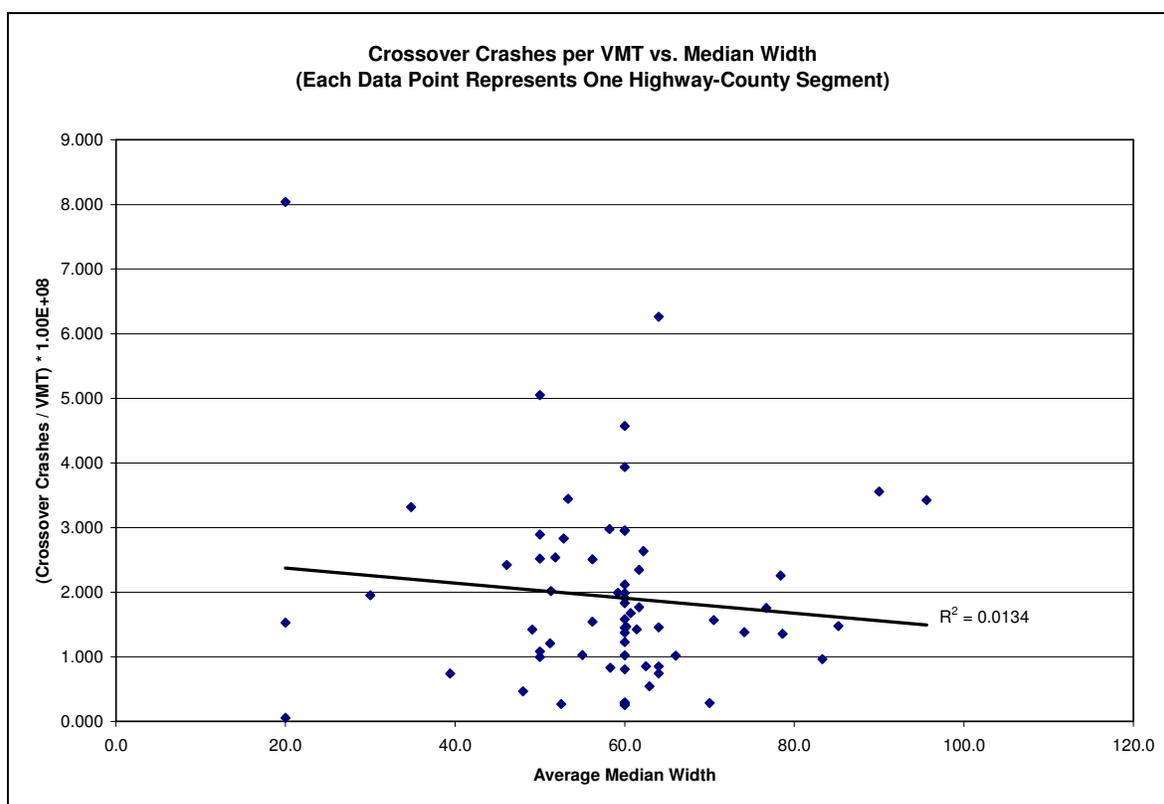


FIGURE 33 Median crossover crash Rates vs. Average Median Width.

In some instances, a vehicle sustained a collision with a vehicle traveling in the same direction on the roadway, but did not make contact with another vehicle after crossing over the median. For this case, such a crash would involve multiple vehicles, but would be classified as a single vehicle type median crossover crash. Table 16 lists the number of crashes for each crossover crash vehicle type. Crashes that involved an object crossing through the median, such as a trailer, are also listed in Table 16. Median crossover crashes initiated by same direction vehicle crashes are further discussed later in this report.

Crash severity was obtained from WisDOT data and the associated accident reports. Crashes were classified as one of three levels of severity: property damage only, personal injury, and fatal. Table 17 lists the number of crashes by crash severity. To best determine the safety improvements that would have the largest impact, it was necessary to determine which median crossover crashes were the most severe. It was believed that crashes involving multiple vehicles, particularly those involving vehicles from opposite directions on the roadway, would be more severe than other median crossover crashes. Figure 34 displays the relationship between the total vehicles involved in a median crossover crash and the severity of a crash.

TABLE 15 Median Crossover Crashes by Total Vehicles Involved

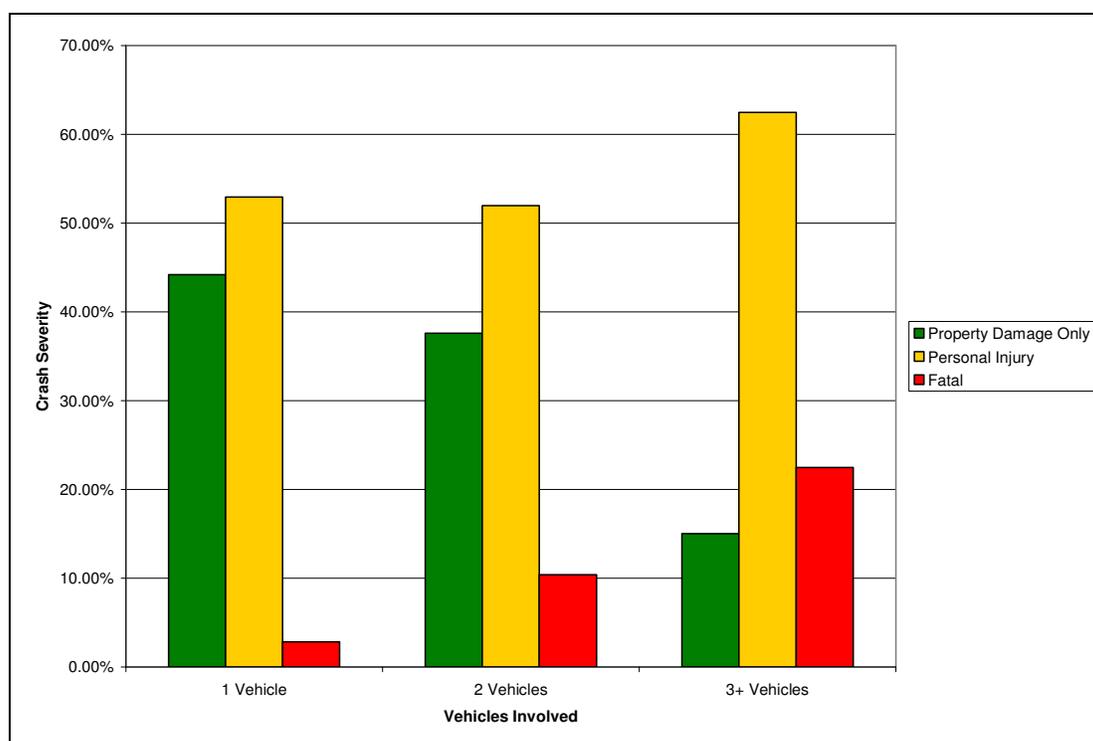
Total Vehicles Involved	Classification	Crashes
1	Passenger Car	389 (61.6%)
	Truck	337
	Motorcycle	47
	Object	1
2	Passenger Car	202 (32.0%)
	Truck	109
	Passenger Car – Passenger Car	8
	Passenger Car – Truck	58
	Object	23
3	Passenger Car	32 (5.1%)
	Truck	5
	Passenger Car – Passenger Car	3
	Passenger Car – Truck	15
4	Passenger Car	5 (0.79%)
	Passenger Car – Passenger Car	1
	Passenger Car – Truck	2
		2
5 or more	Passenger Car	3 (0.48%)
	Passenger Car – Passenger Car	1
Total		631 (100%)

TABLE 16 Median Crossover Crashes by Crash Vehicle Type

Crossover Crash Vehicle Type	Crashes
Single Vehicle Total	511 (81.0%)
Passenger Car	452
Truck	58
Motorcycle	1
Multiple Vehicle Total	113 (17.9%)
Passenger Car – Passenger Car	77
Passenger Car – Truck	35
Truck – Truck	1
Object Total	7 (1.1%)
Trailer	5
Trailer – Passenger Car	2
Total Median Crossover Crashes	631 (100%)

TABLE 17 Median Crossover Crashes by Crash Severity

Crash Severity	Crashes
Property Damage Only	254 (40.3%)
Personal Injury	336 (53.2%)
Fatal	41 (6.5%)
Total	631 (100.0%)

**FIGURE 34 Median Crossover Crash Severity by Total Vehicles Involved.**

As the number of vehicles involved in a median crossover crash increases, the severity of the injuries increases, particularly for fatalities. Fatal crashes make up only three percent of all single vehicle median crossover crashes, increasing to 10 percent of all two vehicle median crossover crashes, and 23 percent of all three or more vehicle median crossover crashes. Median crossover crashes with only property damage drops from 44 percent of all single vehicle crossover crashes to 38 percent of all two vehicle crossover crashes and 15 percent of all three or more vehicle crossover crashes. A complete data summary of median crossover crash severity related to total crash vehicles involved is presented in Table 18.

The median crossover crash vehicle type was analyzed in relation to crash severity. It was hypothesized that crossover crashes that involved the impact of vehicles from opposite directions on the roadway would be more severe, specifically those that involved heavy vehicles. Figure 35 displays the relationship between the median crossover crash vehicle type and the crash severity.

TABLE 18 Median Crossover Crash Severity by Total Vehicles Involved

Crash Severity	Property Damage Only	Personal Injury	Fatal	Totals
Total Vehicles				
1	172 (44.2%)	206 (53.0%)	11 (2.8%)	389 (100%)
2	76 (37.6%)	105 (52.0%)	21 (10.4%)	202 (100%)
3	6 (18.8%)	20 (62.5%)	6 (18.8%)	32 (100%)
4	0	3 (60.0%)	2 (40.0%)	5 (100%)
5+	0	2 (66.7%)	1 (33.3%)	3 (100%)

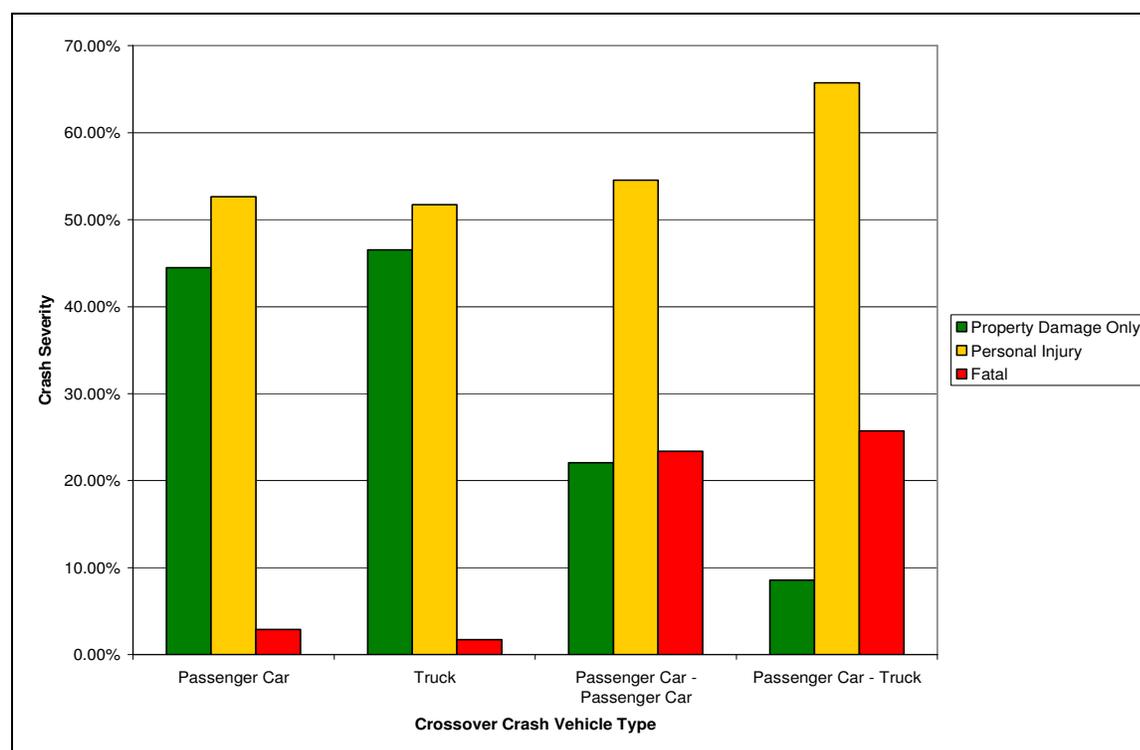


FIGURE 35 Median Crossover Crash Severity by Crossover Crash Vehicle Type.

Similar to the results found through examination of the total number of vehicles involved in a median crossover crash, fatal crashes significantly increase while property damage only crashes noticeably decrease when a vehicle that has crossed the median makes impact with a vehicle traveling in the opposite direction. Only 3.1 percent of all the passenger car or truck single crossover vehicle crashes were fatal compared to 22.3 percent of the passenger car – passenger car or passenger car – truck multiple median crossover vehicle crashes. Conversely, 44.7 percent of all the passenger car or truck single median crossover vehicle crashes involved only property damage as opposed to only 17.9 percent of the passenger car – passenger car or passenger car – truck multiple median crossover vehicle crashes. Motorcycle, truck – truck, trailer, and trailer – passenger car crashes were excluded from Figure 35 due to an insufficient number of crashes. A summary of the median crossover crash severity related to the crossover crash vehicle type is presented in Table 19.

Fatal Median Crossover Crashes

Fatal median crossover crashes are of significant importance due to their high cost, both financially and in terms of loss of life. Over the three year period studied, there were 41 fatal median crossover crashes on the selected roadways resulting in 53 fatalities. Table 20 presents a breakdown of fatal median crossover crashes by vehicles involved and crash vehicle type. Figure 36 displays a map of the locations of the 41 fatal crossover crashes.

To better understand the attributing factors of each fatal crash, specific detail about each fatal median crossover crash should be documented and analyzed. Table 21 presents a detailed breakdown of each of the 41 fatal crashes, including the location of the crash, amount of fatalities, initial causation event, reason for fatality, crash vehicle type, road condition, median width, date of crash, and age of driver.

TABLE 19 Median Crossover Crash Severity by Crash Vehicle Type

Crash Severity		Property Damage Only	Personal Injury	Fatal	Totals
Crossover Crash Vehicle Type					
Single Vehicle Type	Passenger Car	201 (44.4%)	238 (52.7%)	13 (2.9%)	452 (100%)
	Truck	27 (46.6%)	30 (51.7%)	1 (1.7%)	58 (100%)
	Motorcycle	0	1	0	1 (100%)
Multiple Vehicles Type	Passenger Car – Passenger Car	17 (22.1%)	42 (54.6%)	18 (23.4%)	77(100%)
	Passenger Car – Truck	3 (8.6%)	23 (65.7%)	9 (25.7%)	35 (100%)
	Truck – Truck	1	0	0	1 (100%)
Object	Trailer	4 (80.0%)	1 (20.0%)	0	5 (100%)
	Trailer – Passenger Car	1 (50.0%)	1 (50.0%)	0	2 (100%)

TABLE 20 Fatal Median Crossover Crashes by Vehicle Type

		Total Vehicles					Totals
Crossover Crash Vehicle Type		1	2	3	4	5	
Single Vehicle Type	Passenger Car	10	3	0	0	0	13
	Truck	1	0	0	0	0	1
Multiple Vehicles Type	Passenger Car – Passenger Car	0	12	3	2	1	18
	Passenger Car – Truck	0	6	3	0	0	9
Totals		11	21	6	2	1	41



FIGURE 36 Wisconsin Fatal Median Crossover Crashes (2001 – 2003).

Table 21 Fatal Median Crossover Crashes

HW	County	Fatal	Initial Event	Fatality Reason	Crash Type ²	Road Cond	Median Width	Month Year	Driver Age
I-39	Columbia	1	Lost Control	Ejected Passenger	PC-PC	Dry	60	July 01	63
	Dane	1	Snow	Instantly Killed During Rollover	PC-PC	Snow	38	Jan. 02	23
		1	Lost Control	Motorcyclist (Veh 3) – Killed on Impact with Truck	PC – T	Dry	38	July 02	57
		3	Wet Roadway	Driver – Impact; 2 Other Fatalities were other vehicle’s ejected passengers	PC – PC	Wet	38	Oct. 02	16
		1	Lost Control	Driver Ejected	PC – PC	Dry	60	July 03	38
	Marathon	1	Vehicle Collision	Driver Ejected	PC	Dry	60	May 03	58
		1	Wet Roadway	Passenger Killed During Rollover	PC	Wet	60	July 03	27
	Rock	1	Lost Control	Impact with Opposing Direction Truck	PC – T	Dry	60	Oct. 01	56
		1	Lost Control	Killed by Fire that Engulfed Truck Cab on Impact	T	Dry	60	Sep. 03	33
	Waushara	1	Lost Control	Passenger Ejected	PC	Dry	64	May 01	18
	I-43	Manitowoc	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	64	June 02
2			Lost Control	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	88	Aug. 03	18
Milwaukee		1	Lost Control	Driver Ejected	PC	Dry	50	Nov. 01	17
Ozaukee		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	60	June 01	49
		2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	60	Jan. 02	78
I-90	La Crosse	1	Snow	Impact with Opposing Direction Truck	PC – T	Snow	60	Apr. 02	38
I-94	Sauk	1	Snow	Driver Ejected	PC	Snow	60	Nov. 02	40
	Dane	1	Wet Roadway	Impact with Opposing Direction Vehicle	PC – PC	Wet	60	Nov. 03	28
		1	Lost Control	Struck End of Bridge Guardrail on Opposing Direction’s Inner Shoulder	PC	Dry	60	Dec. 03	49
	Eau Claire	1	Lost Control	Fatal Injuries Caused by Rollover	PC	Dry	65	Nov. 03	24
	Jackson	2	Snow	Driver and Passenger Killed on Impact with Truck	PC – T	Snow	85	Mar. 03	20

HW	County	Fatal	Initial Event	Fatality Reason	Crash Type ²	Road Cond	Median Width	Month Year	Driver Age
I-94	St. Croix	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Dec. 01	60
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	28	Sep. 02	47
		3	Ice	Impact with Opposing Direction Vehicle (all 3 persons)	PC – PC	Ice	50	Mar. 03	24
USH 18	Dane	1	Lost Control	Passenger Ejected	PC	Dry	50	Nov. 03	19
USH 41	Brown	1	Ice	Driver Ejected	PC – PC	Ice	60	Nov. 02	20
	Fond Du Lac	2	Wet Roadway	Driver and Passenger Killed on Impact with Opposing Truck	PC – T	Wet	50	Mar. 01	57
		1	Lost Control	Driver Ejected	PC	Dry	50	Apr. 02	20
		4	Lost Control	Driver and Three Passengers Killed on Impact with Opposing Vehicle	PC – PC	Dry	50	Apr. 03	18
	Oconto	1	Lost Control	Driver Ejected	PC	Dry	60	May 01	20
	Winnebago	1	Vehicle Collision	Impact with Opposing Direction Vehicle ¹	PC	Dry	48	Apr. 02	23
		1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	50	Feb. 03	29
	Washington	1	Lost Control	Driver Ejected	PC – PC	Dry	37	Feb. 03	46
USH 51	Marathon	1	Wet Roadway	Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Wet	40	Apr. 01	66
USH 53	Washburn	1	Lost Control	Driver Ejected	PC	Dry	150	July 03	36
USH 151	Columbia	2	Lost Control	2 Passengers Killed on Impact with Opposing Direction Vehicle	PC – T	Dry	90	Nov. 02	22
	Dane	1	Vehicle Collision	Fatal Injuries Caused During Crash	PC	Dry	110	June 02	21
	Dodge	1	Lost Control	Driver Ejected	PC – T	Dry	60	Feb. 01	15
		1	Lost Control	Killed on Impact with Opposing Direction Truck	PC – T	Dry	60	Aug. 01	49
STH 29	Marathon	1	Ice	Killed on Impact with Opposing Direction Truck	PC – T	Ice	64	Jan. 03	47
	Shawano	1	Snow	Killed on Impact with Opposing Direction Vehicle	PC – PC	Snow	60	Mar. 03	21

¹Impact was made with a vehicle that had attempted an illegal u-turn, causing the vehicle documented to traverse the median to the opposing roadway, without striking another vehicle. Fatality occurred in vehicle making illegal u-turn, not the crossover vehicle.

²PC = passenger car; T = truck

As previously mentioned in Chapter 2, a common guideline for determining if a median barrier may be warranted is a 0.12 fatal crashes per mile rate observed for three years out of a five year period. As shown in Figure 37, there is one site, a 5 mile stretch of I-39/I-90/I-94, near the Dane County/Columbia County line, that satisfied this requirement for three out of three years. Figure 38 presents sites that meet the guideline for two out of three years, including locations in Brown, Manitowoc, Oconto, and Ozaukee Counties. Those three fatal crashes are highlighted below in Table 22.

The most common cause of a fatality was impact with an opposing direction vehicle. Approximately 60 percent of the fatalities, 32 out of 53, were due to impact with an opposing direction vehicle. An additional 15 fatalities were due to either a driver or passenger being ejected from a vehicle during a crash. The fact that 28 percent of the fatalities were caused by ejections further stresses the already documented importance of seatbelt use.

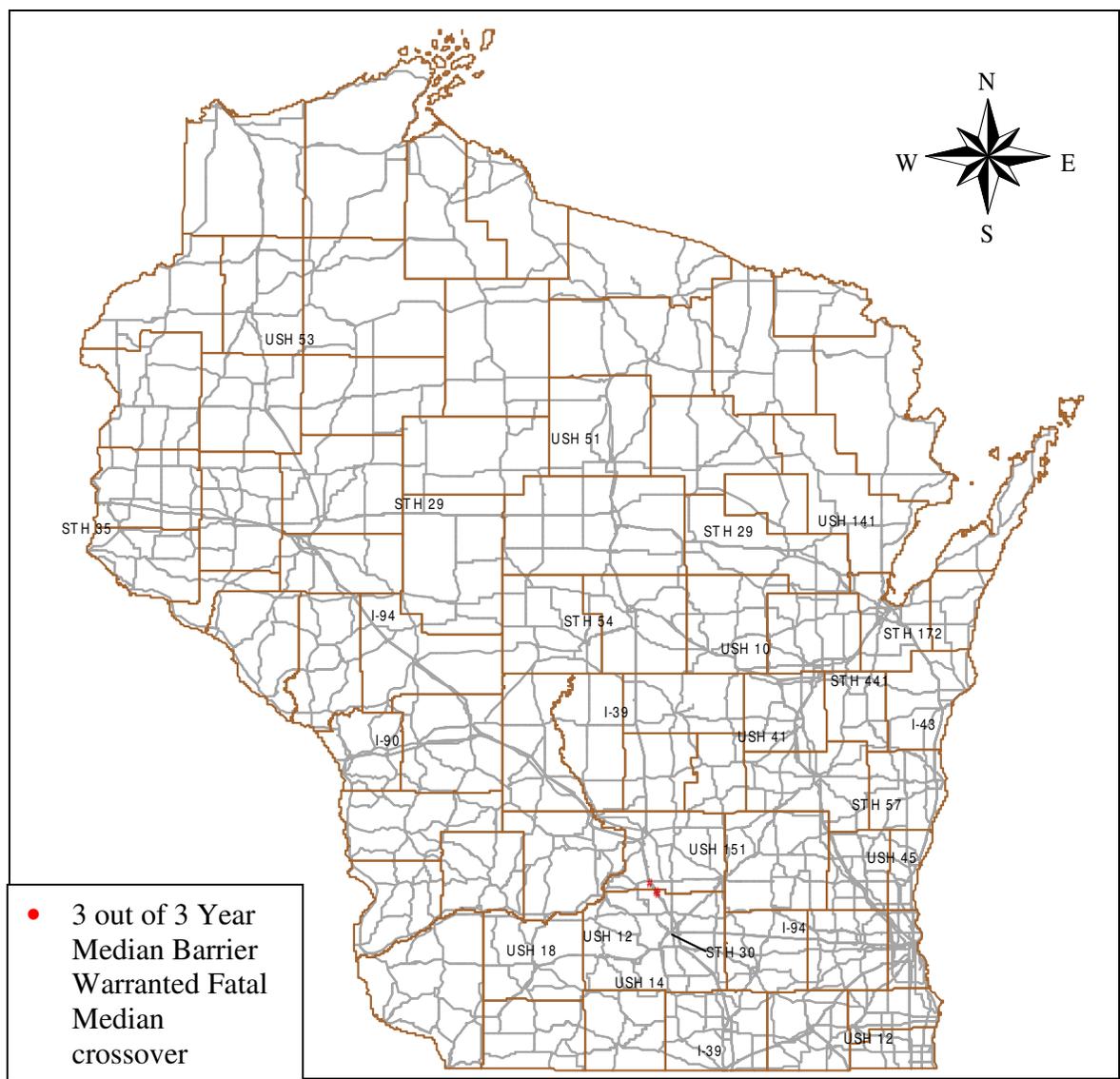


FIGURE 37 Median Barrier Warranted Fatal Median Crossover Crashes (3 Out of 3 Years).

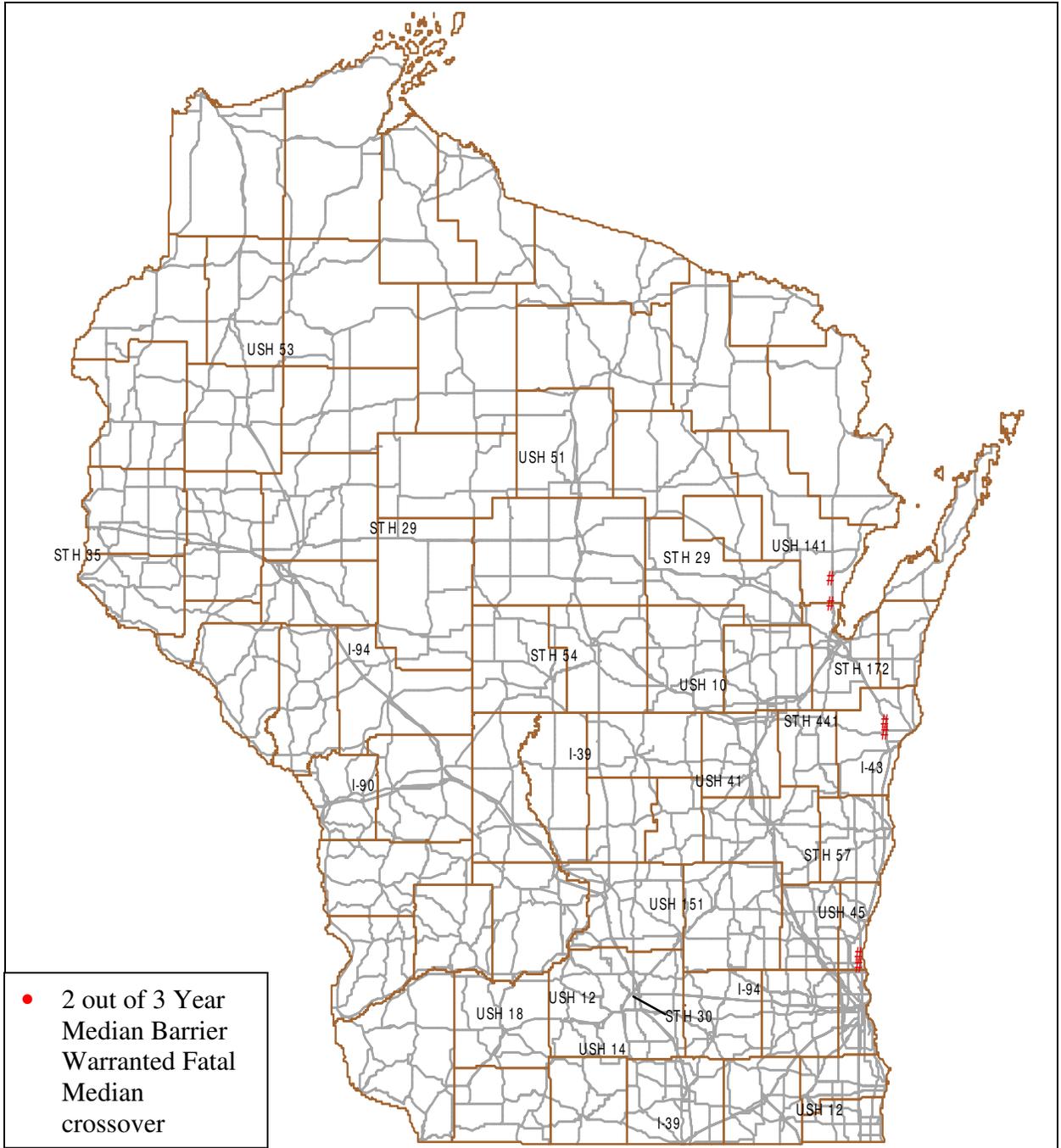


FIGURE 38 Median Barrier Warranted Fatal Median Crossover Crashes (2 Out of 3 Years).

TABLE 22 Median Barrier Warranted Fatal Median Crossover Crashes

HW	County	Fatal	Initial Event	Fatality Reason	Crash Type ²	Road Cond.	Month Year	Driv. Age
I-39	Columbia	1	Lost Control	Ejected Passenger	PC-PC	Dry	July 01	63
	Dane	1	Lost Control	Motorcyclist (Veh 3) – Killed on Impact with Truck	PC – T	Dry	July 02	57
		1	Lost Control	Driver Ejected	PC – PC	Dry	July 03	38
I-43	Manitowoc	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	June 02	40
		2	Lost Control	Driver and Passenger Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	Aug. 03	18
	Ozaukee	1	Lost Control	Impact with Opposing Direction Vehicle	PC – PC	Dry	June 01	49
		2	Lost Control	Two Passengers Killed on Impact with Opposing Direction Vehicle	PC – PC	Dry	Jan. 02	78
USH 41	Brown	1	Ice	Driver Ejected	PC – PC	Ice	Nov. 02	20
	Oconto	1	Lost Control	Driver Ejected	PC	Dry	May 01	20

Median Crossover Crash Extent

A review of the selected crash reports was performed to determine the extent of the crossover in each median crossover crash. Median crossover crashes were classified in one of three categories: partial, into, or beyond. ‘Partial’ median crossover crashes were those in which some portion of the vehicle had crossed the median and came to final rest having entered into at least the shoulder of the opposing roadway. ‘Into’ median crossover crashes were those in which the vehicle had crossed the median and came to final rest within the confines of the opposing roadway. ‘Into’ median crossover crashes include crashes where vehicles completely entered the opposing roadway, though they later came to rest only partially on the opposing roadway surface. ‘Beyond’ median crossover crashes were those in which the vehicle had crossed the median and passed through the opposing lanes before coming to final rest completely beyond the outside shoulder of the opposing roadway. ‘Partial’ crossover crashes accounted for 26.6 percent of the 624 total vehicle crossover crashes, while 39.7 percent were ‘into’ crossover crashes and 33.7 percent were ‘beyond’ crossover crashes. The seven object crossover crashes involving trailers were excluded from this analysis due to the fact that it was not a vehicle which traversed the median. Table 23 presents the data regarding the extent of median crossover and the median crossover crash vehicle type.

TABLE 23 Median Crossover Crash Crossover Extent

Crossover Extent			
Crossover Crash Vehicle Type	Partial	Into	Beyond
Single Vehicle Type Crashes	163 (98.2%)	159 (64.5%)	189 (90.0%)
Passenger Car	135 (81.3%)	145 (58.5%)	172 (81.9%)
Truck	28 (16.9%)	13 (5.2%)	17 (8.1%)
Motorcycle	0	1 (0.4%)	0
Multiple Vehicle Type Crashes	3 (1.8%)	89 (35.9%)	21 (10.0%)
Passenger Car – Passenger Car	2 (1.2%)	58 (23.4%)	17 (8.1%)
Passenger Car – Truck	1 (0.6%)	30 (12.1%)	4 (1.9%)
Truck – Truck	0	1 (0.4%)	0
Totals	166 (100%)	248 (100%)	210 (100%)

Single vehicle type crashes account for 81 percent of all selected median crossover crashes. In other words, 81 percent of single vehicles who crossed over the median and entered the opposing lane found a gap in traffic and did not hit an opposing vehicle. Note that a significant majority of ‘partial’ and ‘beyond’ crossover crashes involve single crossover vehicles. Ninety percent of crossover crashes that went beyond the opposing outside shoulder did not make impact with vehicle traveling in the opposite roadway; the same is true for nearly 98 percent of median crossover crashes that only partially enter the opposing roadway. While a majority of median crossover crashes that come to final rest in the opposite roadway also involve a single crossover vehicle type, the number that escaped opposing traffic is significantly less. Only 64.5 percent of crashes that come to rest in the opposite roadway have no impact with an opposing vehicle, while 35.5 percent of those crashes do collide with another vehicle traveling in the opposite direction. Figure 39 illustrates this point.

The increase in the amount of multiple vehicle type median crossover crashes that come to final rest in the opposing roadway can be explained in two different ways. Vehicles that crossover the median and come to rest in the opposing roadway become obstacles to opposing traffic, increasing the probability that a second, opposing direction vehicle would be involved in the crash. The probability of opposing vehicle crash is less likely when only part of the vehicle is in the roadway or the vehicle has fully cleared the roadway. In another way, vehicles that crossover the median and enter the opposing roadway that do strike a vehicle are much more likely to remain in the opposing roadways surface. Partial median crossover crashes, by their very definition, are less likely to strike another vehicle, and after a collision has occurred affecting the direction and speed of an errant median crossover vehicle, the likelihood of the vehicle continuing beyond the extent of the opposing roadway is reduced.

The number of available gaps of sufficient size in the opposing traffic also affects the likelihood of a multiple vehicle type crash. As the ADT on a roadway increases, the probability of finding a gap of sufficient size to pass through and avoid collision after crossing over the median decreases. Figure 40 displays the percentage of single vehicle type and multiple vehicles type crashes based on ADT. With the exception of the 60,001 – 70,000 vpd range, there is a steady increase in the percentage of multiple vehicles type crashes as the ADT of the roadway increases. Table 24 provides the crash totals for each ADT segment.

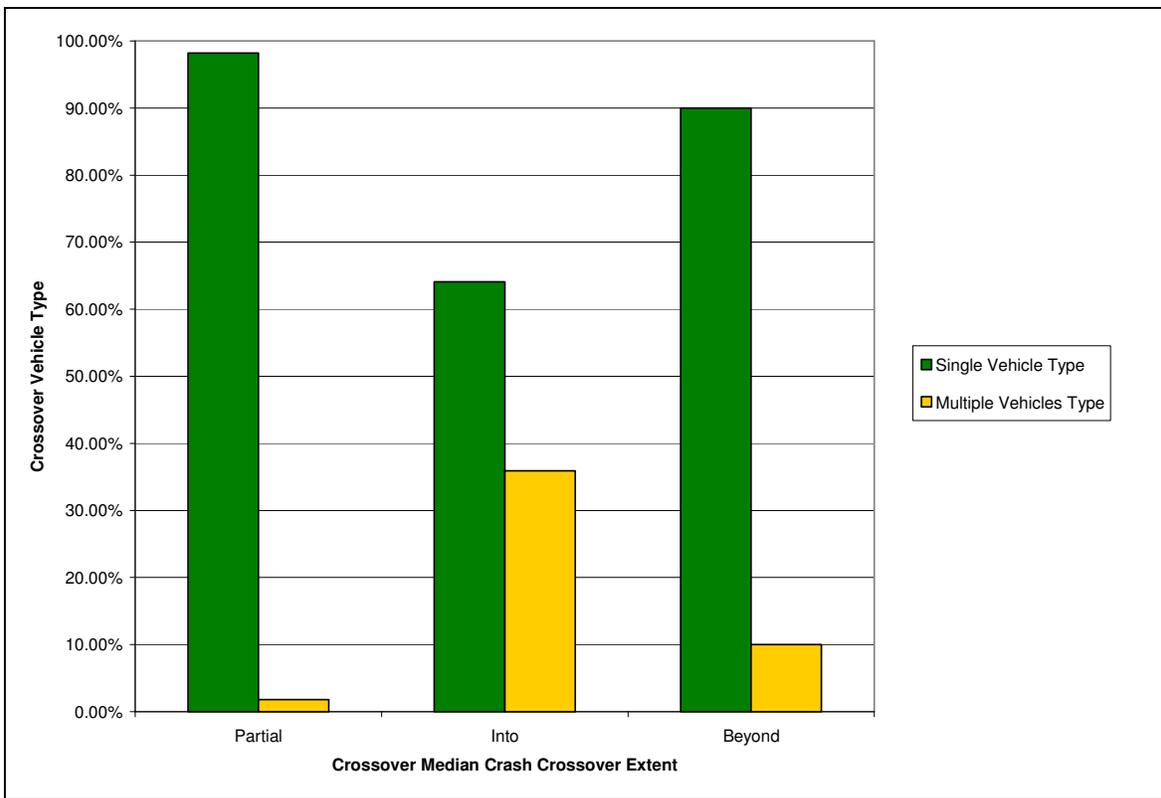


FIGURE 39 Median Crossover Crash Crossover Extent by Vehicle Type.

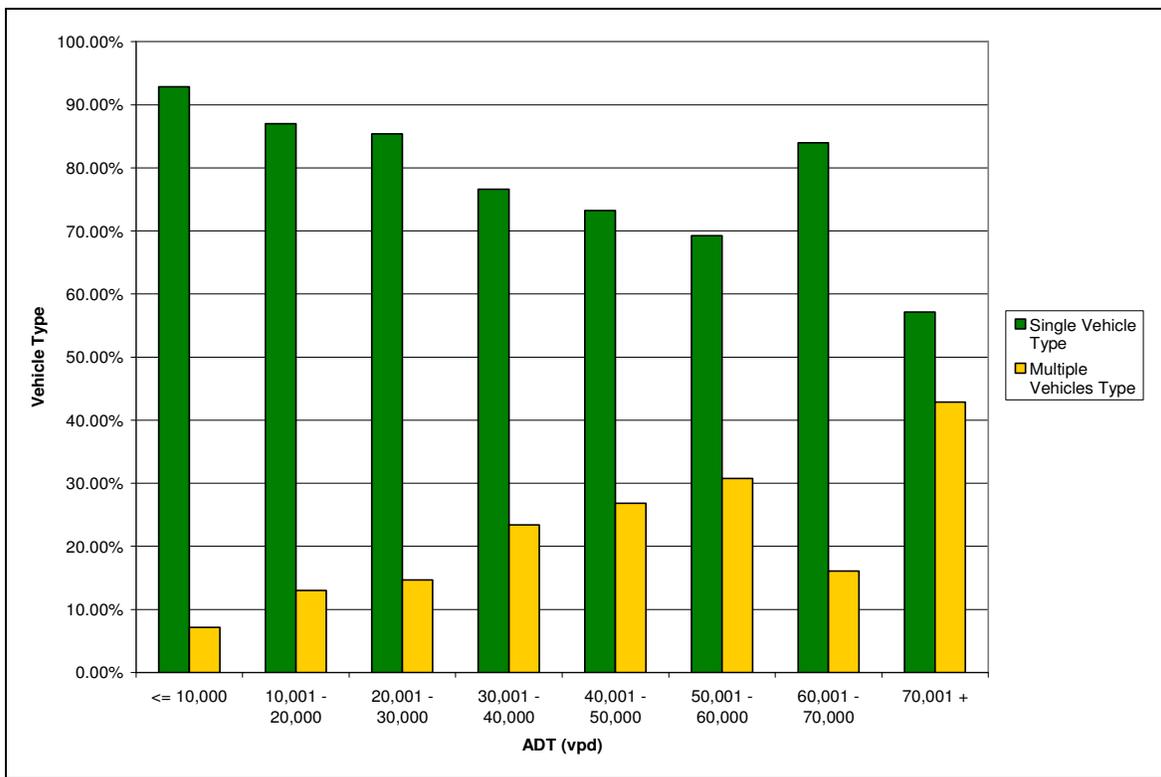
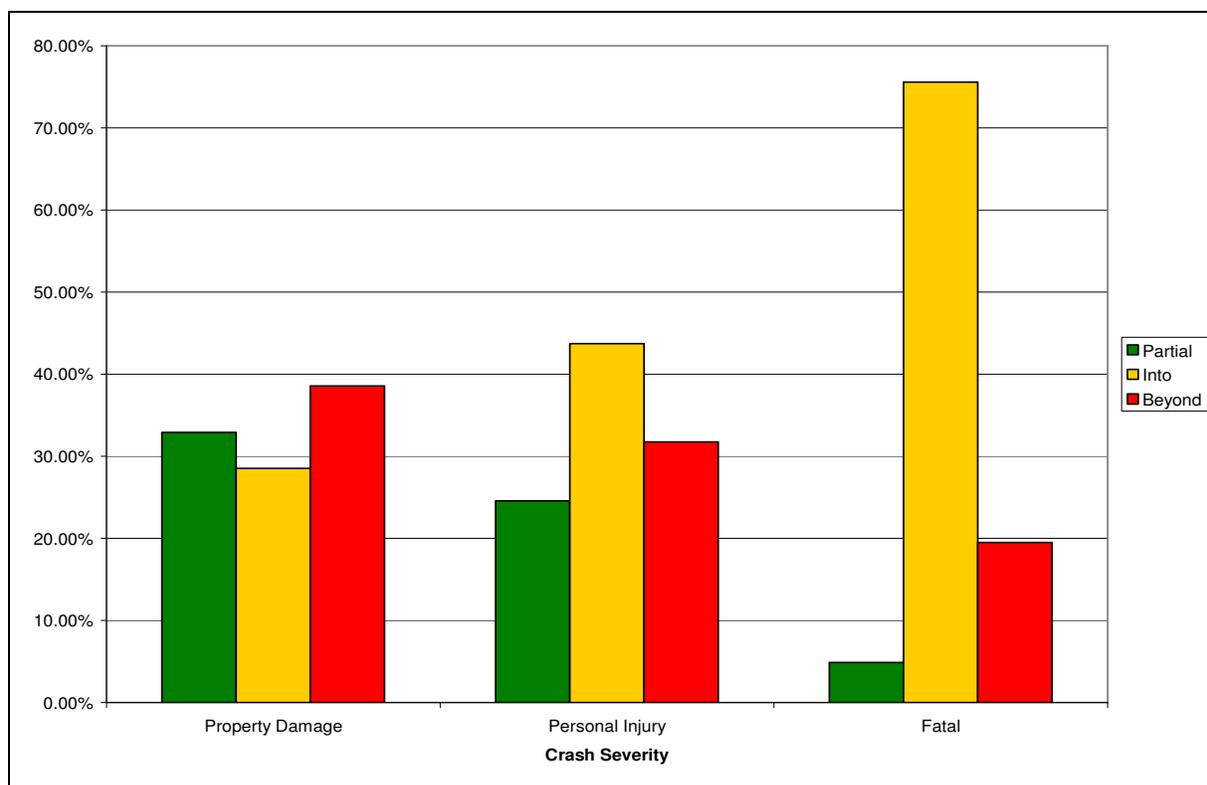


FIGURE 40 Median Crossover Crash Vehicle Type by ADT.

TABLE 24 Median Crossover Crash Vehicle Type by ADT

ADT	Single Vehicle Type	Multiple Vehicles Type
< 10,000	39	3
10,001 – 20,000	154	23
20,001 – 30,000	105	18
30,001 – 40,000	95	29
40,001 – 50,000	41	15
50,001 – 60,000	27	12
60,001 – 70,000	47	9
70,001 +	4	3

Figure 41 displays the crash severity based on the extent of the median crossover by the crash vehicle. Among property damage only crashes, the extent of vehicle crossover is rather evenly distributed. Personal injury crashes that came to their final rest in the opposing roadway begin to separate from those crashes that partially entered the opposing roadway and those that came to final rest beyond the outside shoulder of the opposite roadway. For fatal crashes, those that came to final rest in the opposing roadway make up 75 percent of all fatal crashes. This data substantiates previous findings that multiple median crossover vehicle type crashes, most of which are crashes in which the vehicle traversing the median comes to final rest in the opposing roadway, result in a higher crash severity.

**FIGURE 41 Median Crossover Crash Crossover Extent by Crash Severity.**

During the data collection process, median entry crashes were also quantified. For the roads reviewed for WisDOT District 1 and Districts 3 through 8, the total number of median entry crashes was calculated. District 2 was not included in this analysis as its data collection was done by WisDOT personnel prior to the aforementioned data collection. A median entry crash was classified as one where a vehicle entered the median but did not crossover to the opposing roadway. As with the median crossover crashes, only roadway segments without a median barrier were considered for this data set.

Over the three year study period from 2001 through 2003, 2,562 median entry crashes were found on the roadways examined. Those same roadways were the site of 573 median crossover crashes. This ratio of crashes equates to 22.4 percent. Figure 42 illustrates the results. Slightly more than one out of every five median related crashes involved a vehicle crossing over the median to the opposing roadway.

Vehicle Action at Crash

To better understand driver maneuvers before a median crossover crash occurred, it is important to know a vehicle's actions at the time of the crash. Information regarding each vehicle's actions at the time of the crash was obtained from WisDOT data and the associated median crossover crash reports. As shown in Figure 43, the majority of crashes involved a vehicle or vehicles, going straight on the road at the time of the crash. Vehicles going straight at the time of the crash account for approximately 77 percent of all median crossover crashes. The next most common causes, changing lanes and negotiating a curve, were present in only eight percent and four percent of the total number of median crossover crashes, respectively.

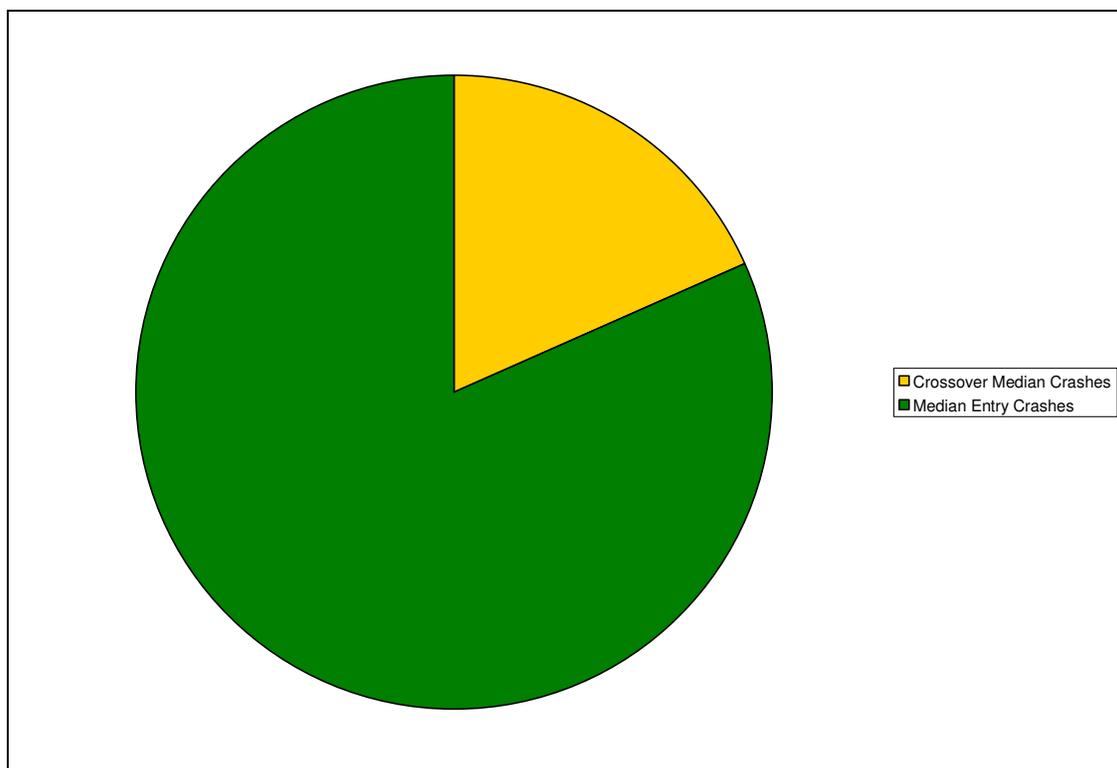


FIGURE 42 Median Related Crashes.

The vehicle action data suggest that median crossover crashes are commonly a result of either driver inattention or a sudden, unexpected change in the driving environment, i.e., stopped traffic ahead, low friction (ice, snow, or water) on the roadway surface, or other conditions that caused a loss of control of the vehicle. Ordinary driving maneuvers, such as negotiating a curve, changing lanes, merging, or passing a vehicle, do not contribute significantly to the median crossover crash total. Table 25 presents a breakdown of the actions performed prior to the 631 median crossover crashes.

TABLE 25 Vehicle Action at Crash

Vehicle Action	Median crossover crashes
Going Straight	486 (77.0%)
Slowing or Stopping	21 (3.3%)
Changing Lanes	50 (7.9%)
Overtaking on Left	21 (3.3%)
Overtaking on Right	8 (1.3%)
Merging	5 (0.8%)
Negotiating Curve	27 (4.3%)
Other	13 (2.1%)
Total	631 (100%)

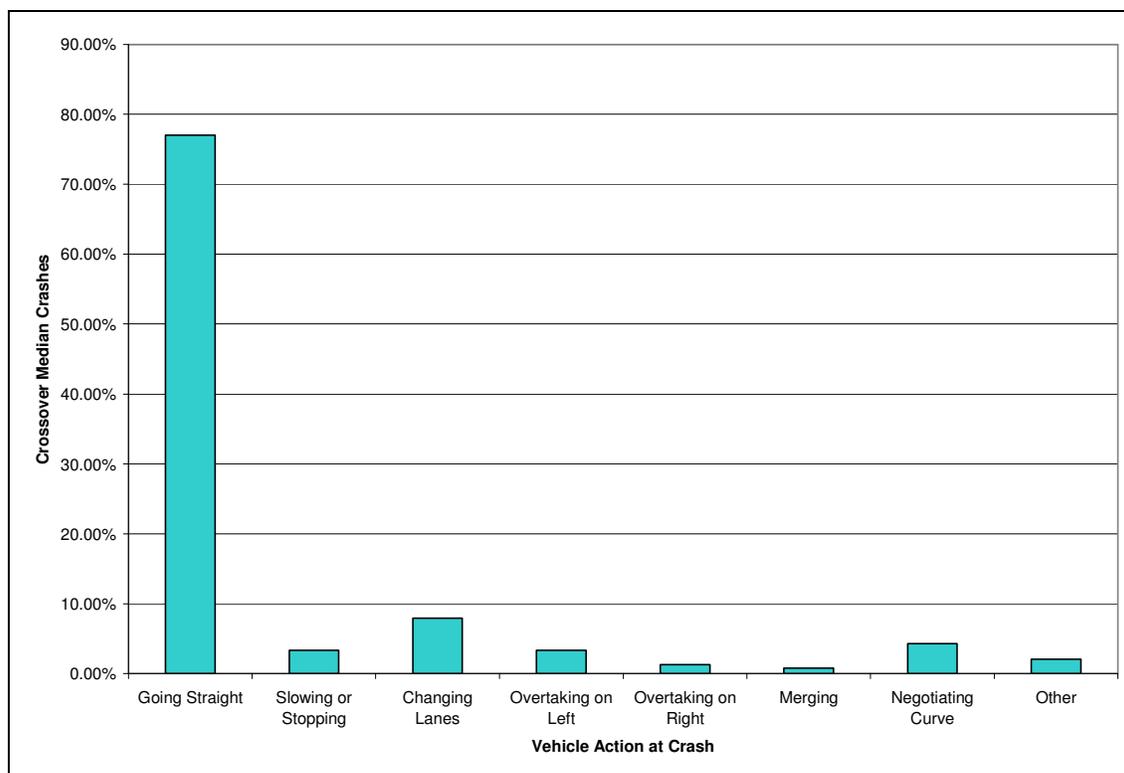


FIGURE 43 Vehicle Action at Crash.

Median Crossover Crash Initial Event

A review of the selected crash reports was performed to determine the most likely initial event leading to each median crossover crash. Even though a variety of factors may have contributed to the outcome, what was sought was the primary or initial factor that generated all the events that followed. Crashes were classified into one of six categories: lost control on dry pavement, lost control due to weather, vehicle collision, barrier, signpost, or other.

Lost control on dry pavement crashes were median crossover crashes in which the initial event was loss of control of the vehicle by the driver on dry pavement, resulting in the vehicle traversing the median and entering the opposing roadway. This loss of control categorizes a wide range of possibilities, including avoidance maneuvers, distractions, blackouts, inattentiveness, and other related reasons.

Lost control due to weather crashes were median crossover crashes where, regardless of other actions contributing to the crash, weather and associated pavement conditions were the dominant factor for loss of control. Weather issues related to the condition of the roadway, including snow, ice, and a wet roads from rain. There was also one crash involving a truck which lost control due to high crosswinds.

Vehicle collision crossover crashes were crashes in which an impact with a vehicle traveling in the same direction precipitated a vehicle to traverse the median and enter the opposing roadway. These crashes may be classified as either single vehicle crossover type crashes or multiple vehicles type crossover crashes. All vehicle collision crashes are multiple vehicle crashes due to the fact that they involve a collision between vehicles traveling in the same direction. However, many are single vehicle type crashes due to the fact that only one vehicle crosses over the median into the opposing roadway. Out of the 70 vehicle collision crashes, 64 (91 percent) only involved one vehicles crossing over the median to the opposing roadway. Single passenger cars were the only vehicle that crossed over the median for 61 crashes; three vehicle collision crashes resulted in a single truck crossing the median to the opposing roadway. Only in six instances did multiple vehicles crossover the median due to a vehicle collision between vehicles traveling in the same direction. The collision between two passenger cars accounted for four crashes; the other two involved the collision of a passenger car and a truck.

Barrier median crossover crashes were crashes in which a vehicle initially struck a roadway barrier, which caused the vehicle to traverse the median and enter the opposing roadway. Four of these instances involved guardrails, one a concrete barrier. Signpost median crossover crashes were crashes in which a vehicle struck the post of a sign or delineator, causing the driver to lose control of the vehicle and traverse the median ultimately entering the opposing roadway.

Three median crossover crashes could not be classified by the other five categories and were grouped together under the term 'other'. Two median crossover crashes were initiated by a deer hit and construction barricade hit. Each of these crashes involved a single passenger car. The third 'other' median crossover crash involved a vehicle that was initially struck by a stray tire from a truck traveling on the opposing roadway, which in turn caused the vehicle struck by the tire to loss control and cross over the median into the opposing roadway. This crash was classified as a multiple vehicle crash as the vehicle that crossed the median then struck two other

passenger cars. Figure 44 displays the breakdown of the initial causes for the median crossover crashes, excluding those crashes in which an object, not a vehicle, traversed the median.

The two largest initial causes for median crossover crashes, lost control on dry pavement and loss of control due to weather, make up a significant amount of the total number of crossover crashes. Of the 624 vehicle crossover crashes, 541, or 86.7 percent, of those crashes were related to either adverse weather conditions or by a loss of control by the driver. Only 13.3 percent of the crashes were due to a collision with another vehicle or object. With the exception of one crash that was caused by strong crosswinds, weather related crashes could be broken down into the road conditions ice, snow, and wet. Figure 45 displays the breakdown of weather-caused median crossover crashes. Table 26 presents a breakdown of the causes for all 631 selected median crossover crashes.

Another way to examine the effect of weather-caused median crossover crashes is to look specifically at the roadway condition at the time of the crash. Figure 46 shows the road condition for all median crossover crashes. Dry pavement was the prevailing road condition, being present for 347 (55.6 percent) of the median crossover crashes. Again the seven object median crossover crashes were excluded.

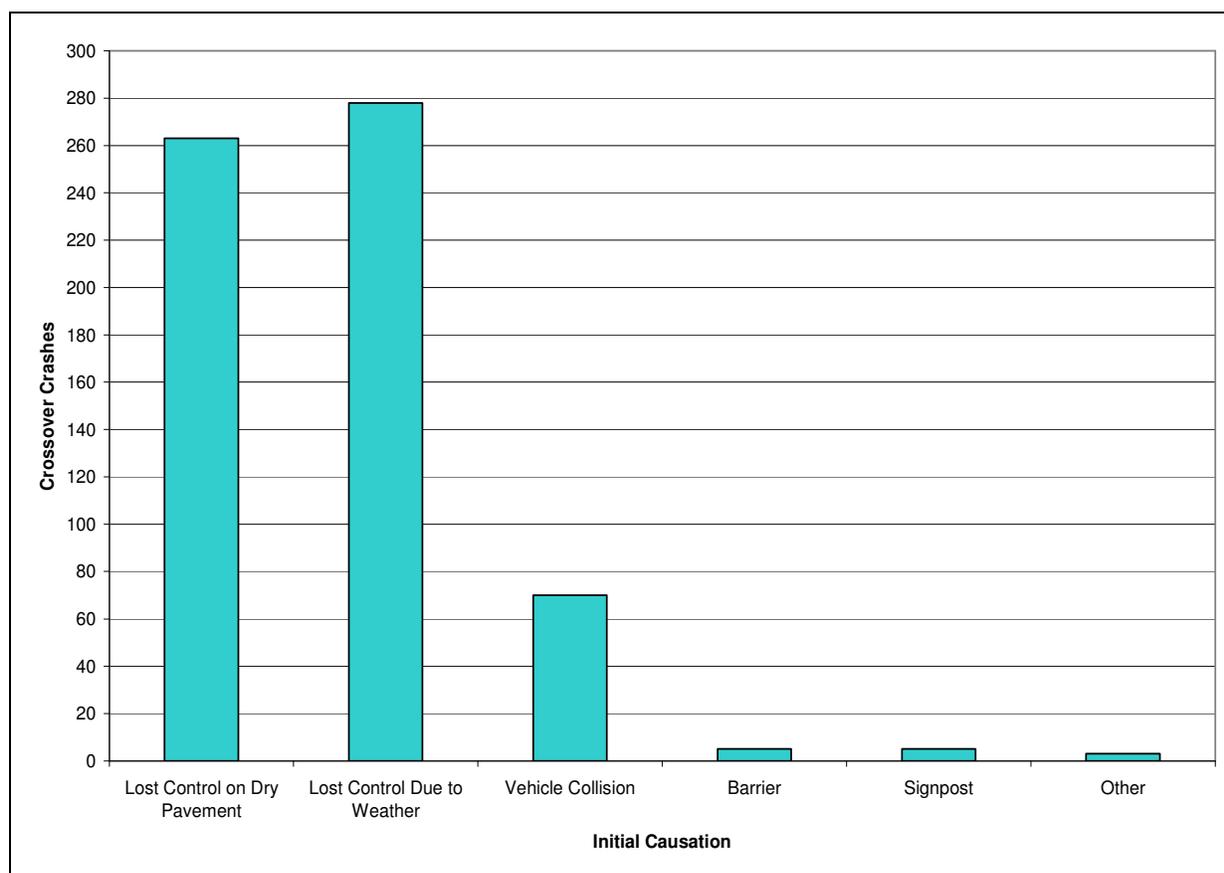


FIGURE 44 Median Crossover Crashes by Initial Causes.

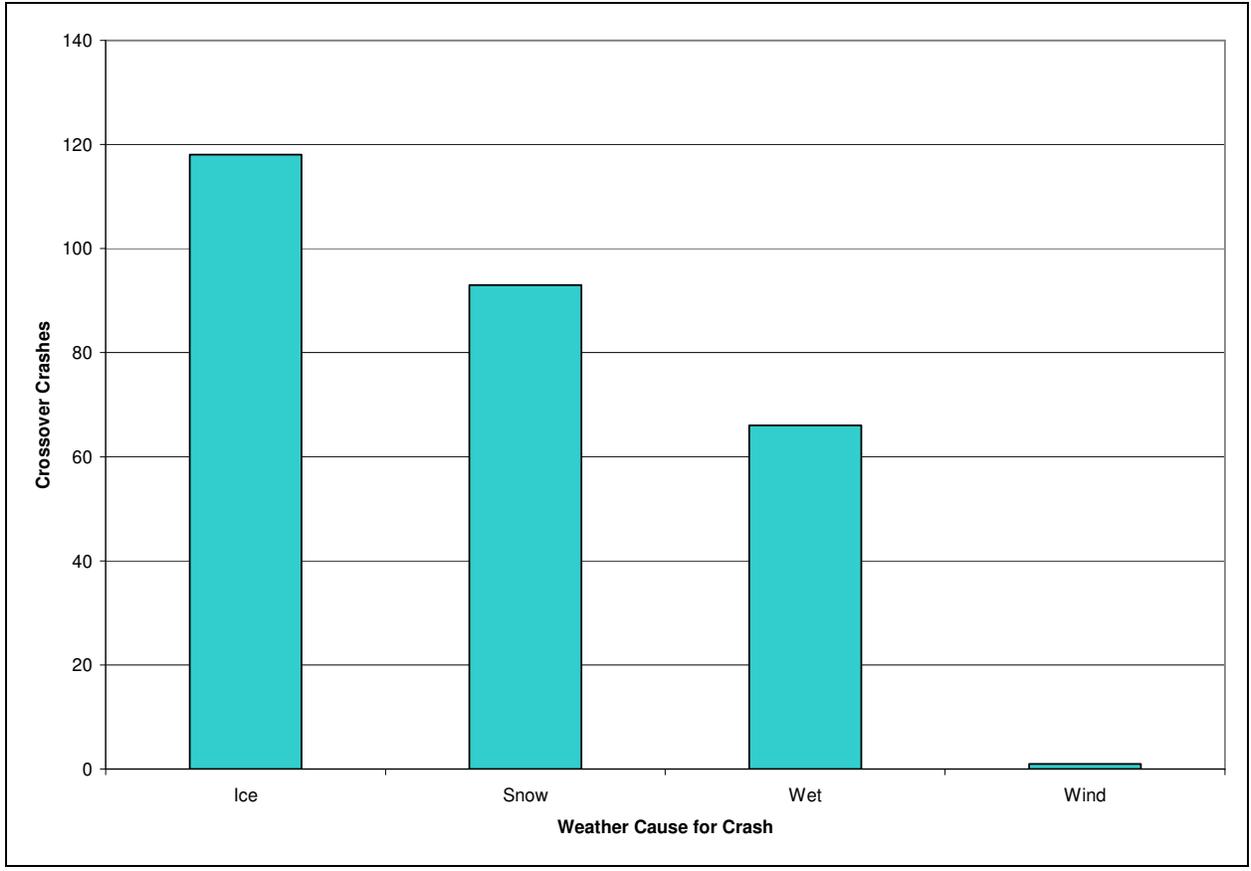


FIGURE 45 Weather-Related Crossover Crash Breakdown.

TABLE 26 Median Crossover Crashes by Initial Causes

Initial Cause of Crash	Crashes
Lost Control on Dry Pavement	263 (41.7%)
Lost Control Due to Weather	278 (44.0%)
<i>Ice</i>	<i>118</i>
<i>Snow</i>	<i>93</i>
<i>Wet</i>	<i>66</i>
<i>Wind</i>	<i>1</i>
Vehicle Collision	70 (11.1%)
Barrier	5 (0.8%)
Signpost	5 (0.8%)
Other	3 (0.5%)
Object / Trailer Crashes	7 (1.1%)
Total Crossover Crashes	631 (100%)

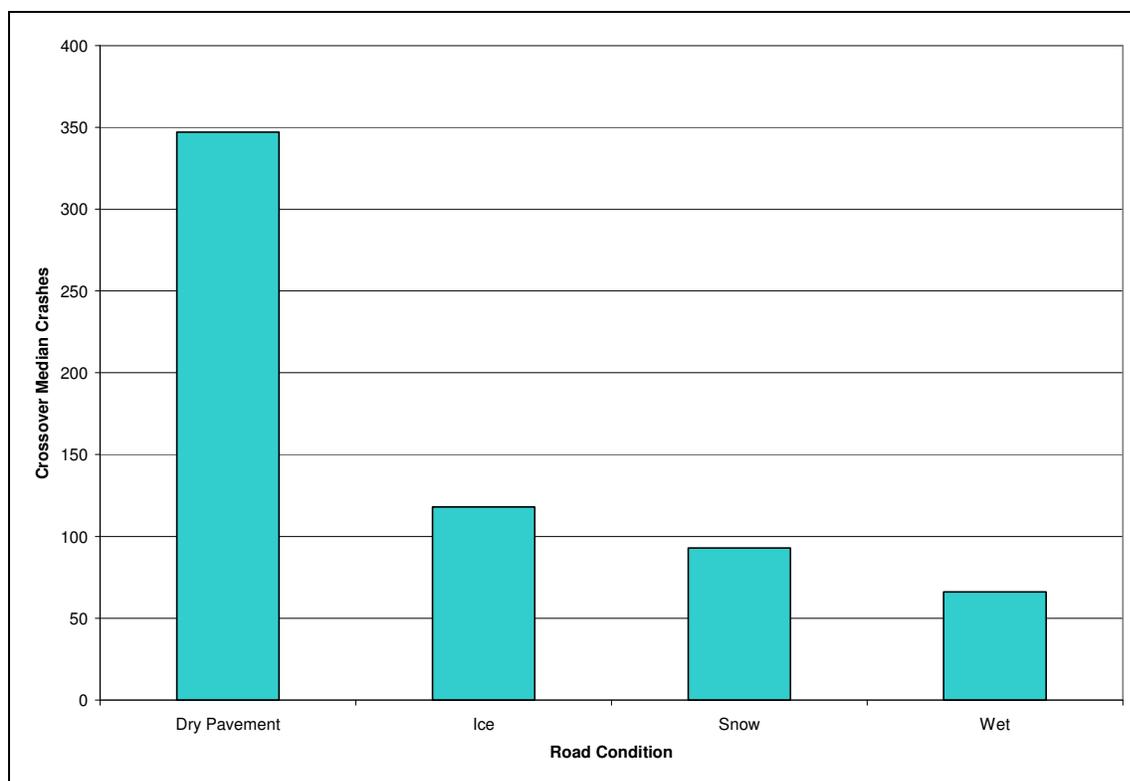


FIGURE 46 Road Condition for Median Crossover Crashes

Lost control on dry pavement and loss of control due to weather were determined to be the two dominant initial actions that caused a median crossover crash, each with similar totals. To understand the different types of crossover crashes and what leads to the most severe crashes, the six initial causations were examined to see how many crashes of each cause were property damage only, personal injury, and fatal. Figure 47 displays the results. Weather is the dominant cause of property damage only median crossover crashes, while lost control and weather represent the same amount of personal injury crossover crashes. However, for fatal crashes, loss of control on dry pavement is the dominant initial action that causes a median crossover crash.

Table 27 presents full results of the initial causation for each median crossover crash according to crash severity. A possible explanation for the noticeably fewer weather-caused fatal crossover crashes may be due to changes in driver behavior. With ice, snow, or wet road conditions, many drivers drive at slower speeds with more caution. Another reason may be due to fewer vehicles on the roadway because of bad weather.

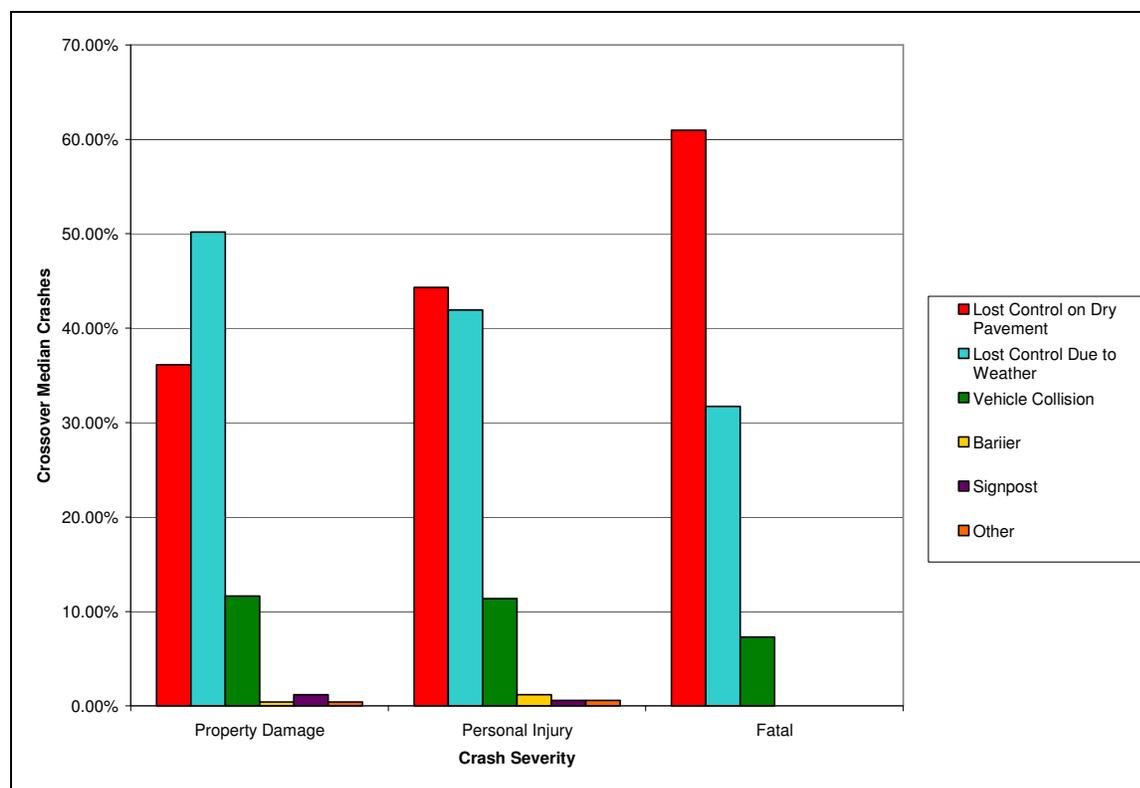


FIGURE 47 Median Crossover Crash Initial Causation by Crash Severity.

TABLE 27 Median Crossover Crash Initial Causation by Crash Severity

Initial Cause of Crash	Property Damage Only	Personal Injury	Fatal
Lost Control on Dry Pavement	90 (36.1%)	148 (44.3%)	25 (61.0%)
Lost Control Due to Weather	125 (50.2%)	140 (41.9%)	13 (31.7%)
<i>Ice</i>	53	62	3
<i>Snow</i>	44	43	6
<i>Wet</i>	28	34	4
<i>Wind</i>	0	1	0
Vehicle Collision	29 (11.7%)	38 (11.4%)	3 (7.3%)
Barrier	1 (0.4%)	4 (1.2%)	0
Signpost	3 (1.2%)	2 (0.6%)	0
Other	1 (0.4%)	2 (0.6%)	0
Total Vehicle Crossovers	249 (100%)	334 (100%)	41 (100%)
Object / Trailer Crashes	5	2	0
Total Crossover Crashes	254	336	41

Crossover Crash Demographics

Researchers were specifically interested in the demographic and related attributes of each median crossover crash. All demographic information related to the selected crossover crashes were obtained from WMVAR data. The dates of the median crossover crashes were grouped together by month. Figure 48 displays a month-by-month breakdown of the selected median crossover crashes. Though some months showed fluctuation from year to year, the three year averages show a definite pattern of an increase in median crossover crashes during winter weather months, December to April. This finding appears to be consistent with previous results as 76 percent of the median crossover crashes caused by weather were due to ice or snow covered roadways, conditions that are most prevalent during that five month period. Table 28 presents a complete breakdown of the crossover crashes by month according to the initial cause of the crash.

Approximately 80 percent of the weather-caused median crossover crashes occurred during the five month period of December to April. The increase in median crossover crashes during winter months contrasts with average annual daily traffic (AADT) data. AADT on the selected roadways is greater during the summer months. Presented in Table 29, 2003 AADT for five of the median barrier warranted “hot spots” was averaged to generate a percentage of AADT for each month (37). As illustrated in Figure 49, AADT for Wisconsin peaks during the summer in August, with the lowest volumes during the winter months from January through March. This result shows little correlation between AADT and median crossover crash frequency as three of the four highest months for median crossover crashes are January, February, and March.

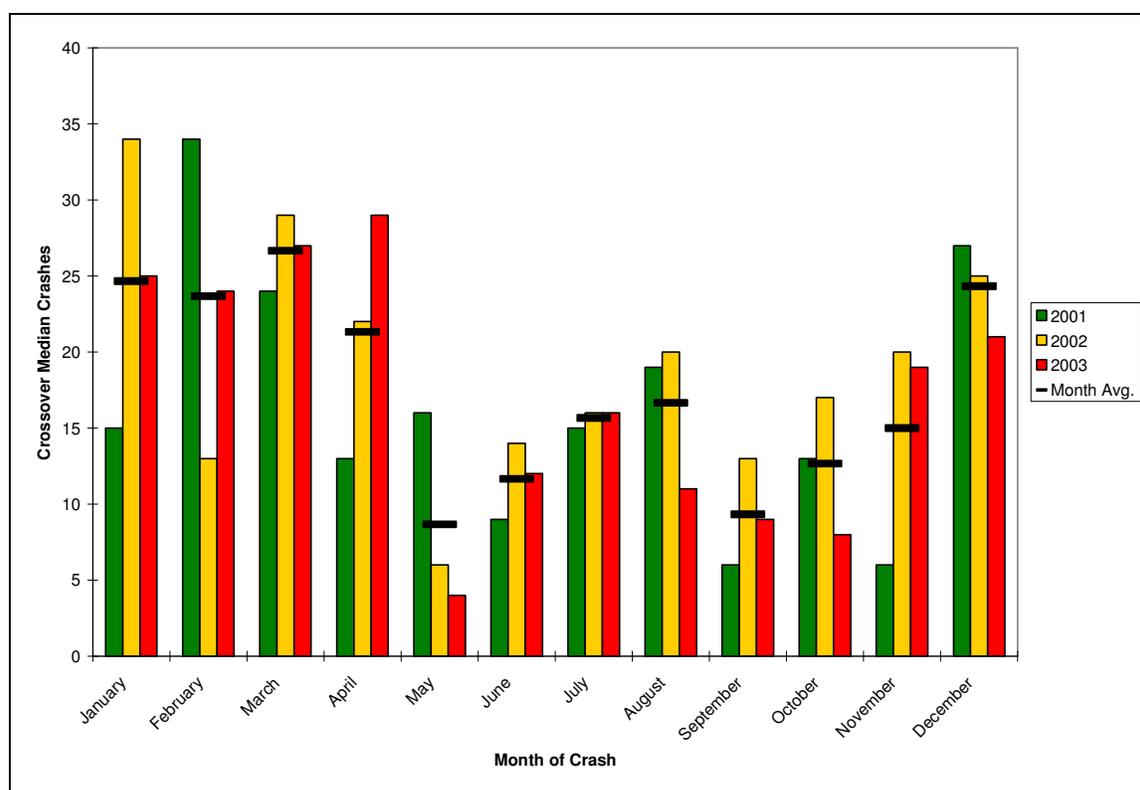
The age of drivers involved in median crossover crashes were grouped into ten-year segments, beginning with the youngest drivers involved – fifteen year-olds – up to a final segment of drivers 80 years of age or older. Figure 50 displays the results of 630 crossover crashes; one crash was a hit and run with a trailer crossover, so no age was available.

TABLE 28 Monthly Crossover Crashes by Initial Causation

Initial Cause of Crash	Lost Control on Dry Pavement	Lost Control Due to Weather	Vehicle Collision	Barrier	Sign Post	Other	Object / Trailer
Month							
January	17	52	5	0	0	0	0
February	21	44	4	0	1	0	1
March	20	54	4	1	0	0	1
April	21	38	5	0	0	0	0
May	20	4	2	0	0	0	0
June	20	6	6	1	1	1	0
July	30	5	9	2	0	0	1
August	31	9	8	0	1	0	1
September	18	4	6	0	0	0	0
October	21	11	5	0	1	0	0
November	22	18	3	0	0	1	1
December	22	33	13	1	1	1	2
Totals	263	278	70	5	5	3	7

TABLE 29 ADT for Wisconsin Median Crossover Crash Hotspots

Month	Dane I-39/I-90		Columbia I-39/ I-90/I-94		Dodge USH 151		Fond Du Lac USH 41		Brown USH 41		WI Avg.
	ADT	%	ADT	%	ADT	%	ADT	%	ADT	%	%
Jan	64,894	6.6	42,382	6.3	13,759	6.9	26,195	6.8	33,912	7.4	6.8
Feb	69,409	7.1	44,703	6.6	14,214	7.1	27,407	7.1	35,161	7.6	7.1
Mar	72,120	7.4	48,049	7.1	15,215	7.6	28,248	7.3	36,042	7.8	7.5
Apr	96,664	9.9	51,196	7.6	16,258	8.1	30,141	7.8	36,025	7.8	8.2
May	82,319	8.4	56,891	8.5	16,806	8.4	33,240	8.6	37,663	8.2	8.4
Jun	86,139	8.8	64,851	9.6	17,922	8.9	34,923	9.0	40,101	8.7	9.0
Jul	91,647	9.4	72,488	10.8	18,011	9.0	37,280	9.6	40,405	8.8	9.5
Aug	93,980	9.6	72,918	10.8	19,014	9.5	38,911	10.0	43,470	9.4	9.9
Sep	83,144	8.5	58,452	8.7	17,638	8.8	34,247	8.8	40,280	8.7	8.7
Oct	83,160	8.5	57,068	8.5	18,249	9.1	33,682	8.7	41,254	8.9	8.7
Nov	78,363	7.0	54,379	8.1	17,203	8.6	32,695	8.4	38,784	8.4	8.3
Dec	74,848	7.7	48,686	7.2	16,563	8.2	30,315	7.8	37,615	8.2	7.8

**FIGURE 48 Median Crossover Crashes by Month.**

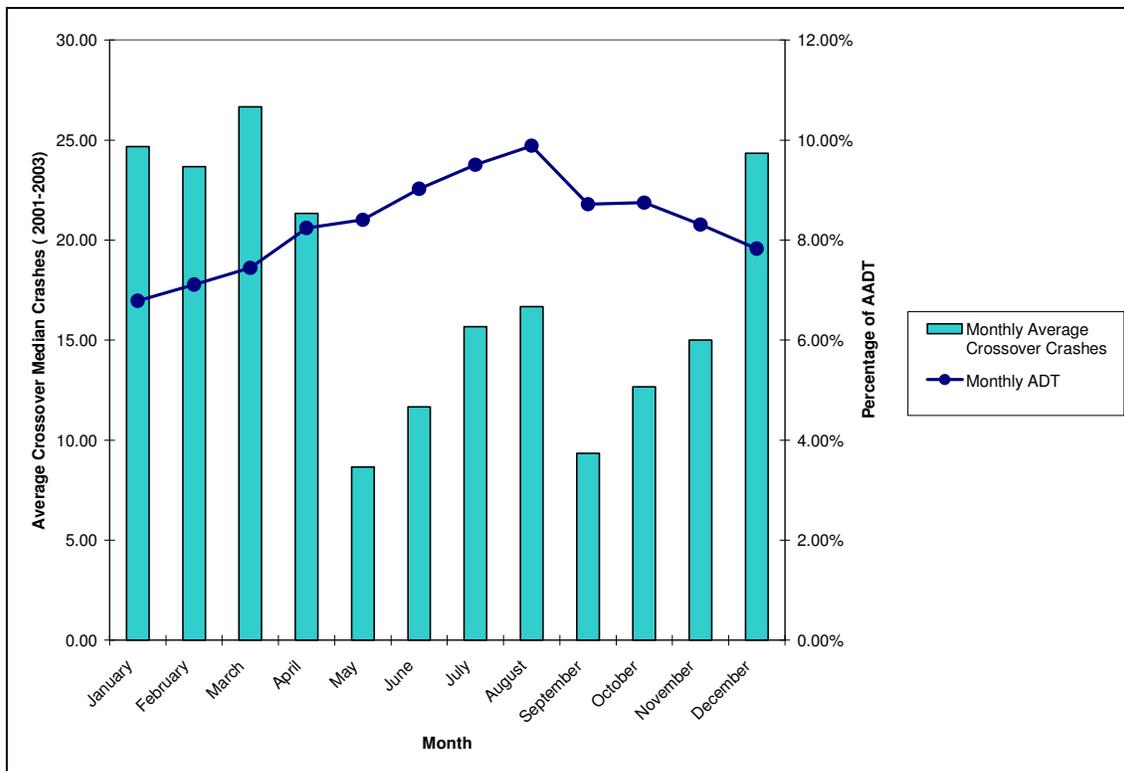


FIGURE 49 Monthly Median Crossover Crashes and ADT.

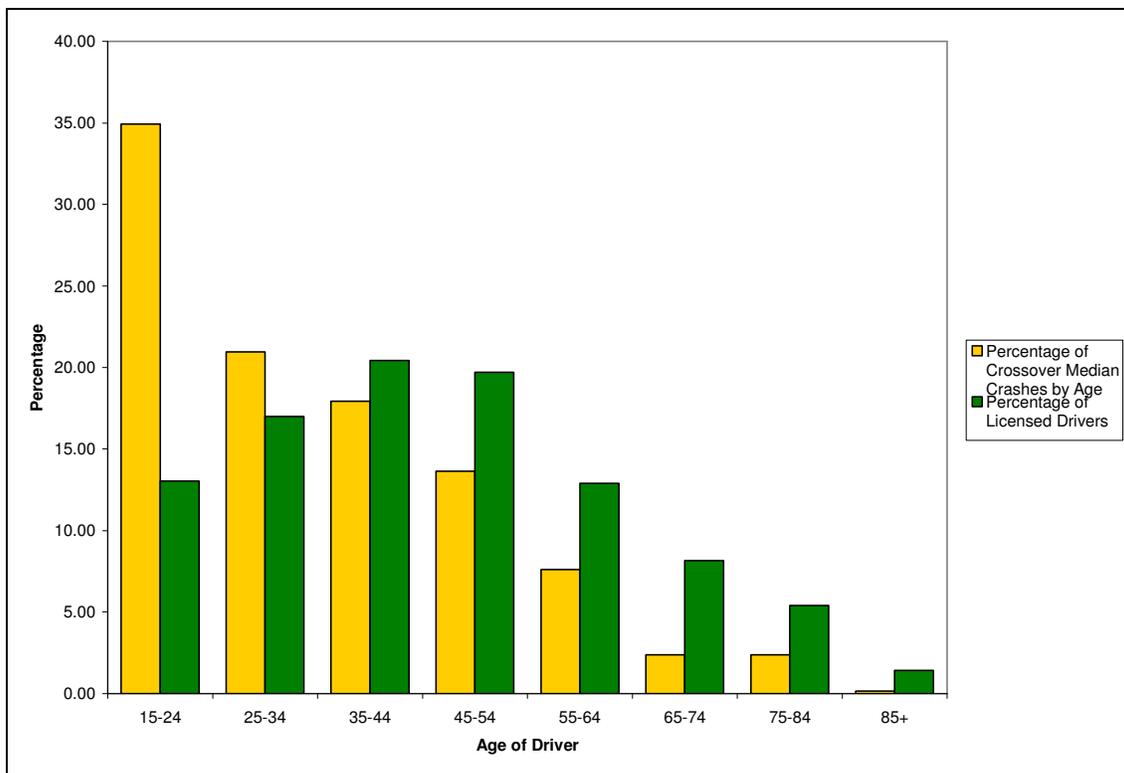


FIGURE 50 Median Crossover Crashes by Age of Driver.

The single largest cohort was drivers aged 15 to 24. Approximately 35 percent of the median crossover crashes involved drivers under the age of 25. Numbers did not drop off sharply at the age of 25, but they began a steady decline. Table 30 presents the breakdown of crossover crashes by the age of the driver. When examined as a rate, the significance of the age of the driver in a median crossover crash becomes more pronounced.

Using 2003 licensed driver data from WisDOT's 2003 Wisconsin Traffic Crash Facts, the number of median crossover crashes by age were calculated as a rate of the total drivers for each age bracket (38). Figure 51 displays the results, clearly showing that younger drivers are more likely to be involved in a median crossover crash. The crossover crash rate of drivers under the age of 25 is almost twice as high as drivers aged 25 to 34, and three to four times higher than drivers aged 45 and over. There is a small spike in the crossover rate for drivers aged 75 to 84. The small amount of driving done by licensed drivers aged 85 and over explains the reason the spike in crossover crash rate does not continue. Table 31 presents the crash rates by age.

Alcohol was marked as a factor on the WMVAR for 69 median crossover crashes, or 10.9 percent of all the selected median crossover crashes. The exact blood-alcohol level (BAC) was not recorded. Among the alcohol-related crossover crashes, the following facts were found:

- Initial Cause of Crash
 - 62.3 percent were lost control median crossover crashes
 - 18.8 percent weather-related median crossover crashes
 - 15.9 percent were vehicle collision median crossover crashes
 - 2.8 percent were barrier crashes
- Crash Vehicle Type
 - 89.9 percent were single median crossover vehicle type crashes
 - 60 passenger car crashes
 - 2 truck crashes
 - 10.1 percent were multiple median crossover vehicle type crashes
 - 4 passenger car – passenger car crashes
 - 3 passenger car – truck crashes

TABLE 30 Median Crossover Crashes by Age of Driver

Age of Driver	Median Crossover Crashes		Licensed Drivers	
	Number	Percent	Number	Percent
15-24	220	34.9	589,180	15.0
25-34	132	20.9	668,542	17.0
35-44	113	17.9	803,469	20.4
45-54	86	13.6	775,496	19.7
55-64	48	7.6	507,559	12.9
65-74	15	2.4	320,568	8.1
75-84	15	2.4	212,697	5.4
85+	1	0.1	56,143	1.4
Unknown	1	0.1	-	-
Total	631	100	3,933,654	100

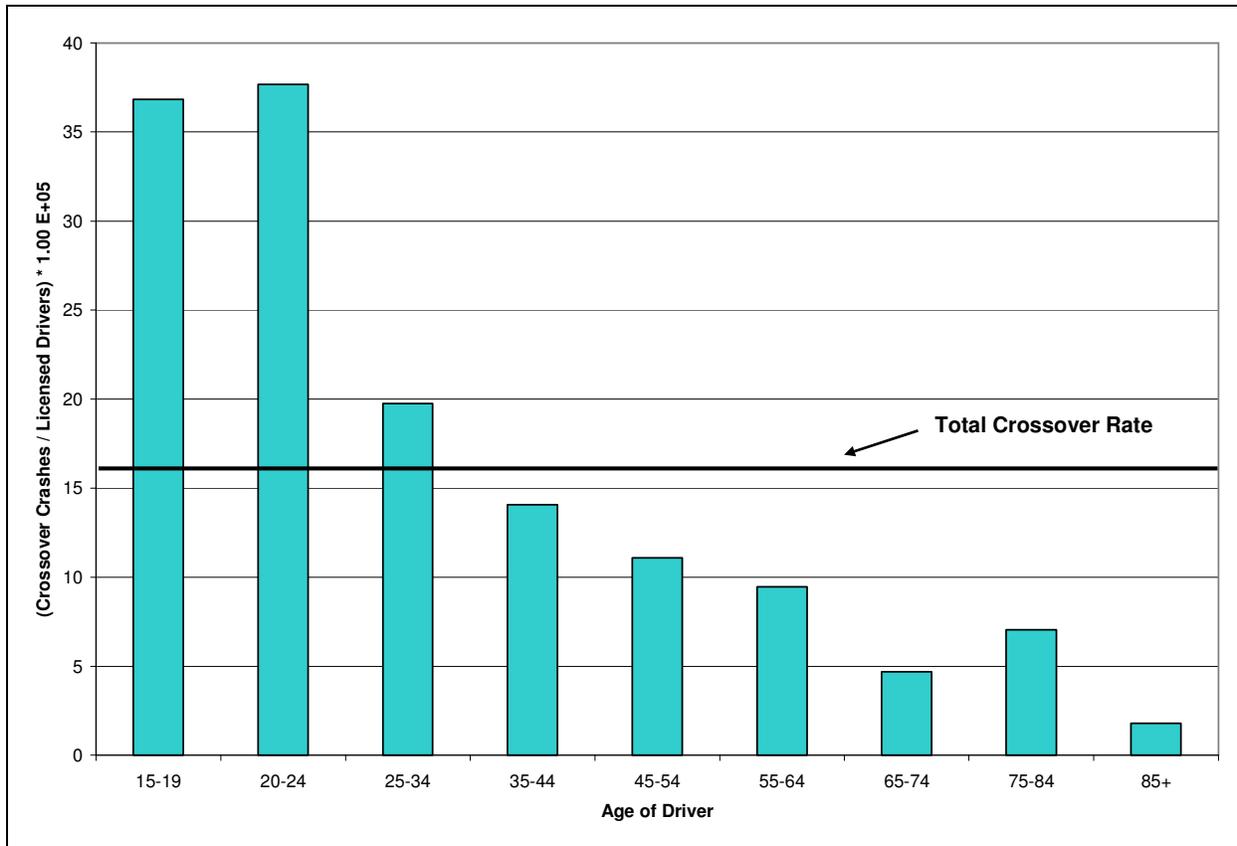


FIGURE 51 Median Crossover Crash Rate by Age of Driver.

TABLE 31 Median Crossover Crash Rate by Age of Driver

Age of Driver	Crashes	Wisconsin Licensed Drivers	Crossover Crash Rate (* 1.00 E+05)
15-19	85	230,787	36.83
20-24	135	358,393	37.67
25-34	132	668,542	19.74
35-44	113	803,469	14.06
45-54	86	775,496	11.09
55-64	48	507,559	9.46
65-74	15	320,568	4.68
75-84	15	212,697	7.05
85+	1	56,413	1.78
Unknown	1	N/A	N/A
Total	631	3,933,654	16.04

- Crash Severity
 - 37.7 percent were property damage only crashes
 - 52.2 percent were personal injury crashes
 - 10.1 percent were fatal crashes

- Age of Driver
 - 47.8 percent were crashes with drivers under the age of 25
 - 73.9 percent were crashes with drivers under the age of 35

Alcohol-related crashes were examined to determine whether the alcohol-flagged driver was in the vehicle that crossed over the median or if the driver had caused another vehicle to crossover the median. Of the 69 alcohol-related crashes, 48 involved a single vehicle, accounting for 70 percent of the alcohol-related median crossover crashes. Of the remaining 21 crashes, the alcohol-flagged driver crossed the median in 13 cases while another vehicle crossed over the median in only three cases. It was unknown which driver was cited for alcohol in five cases because the information was unavailable. When totaled, 61 out of 69 alcohol-related median crossover crashes occurred when an alcohol-flagged driver crossed over the median, as opposed to only three crashes where an alcohol-flagged driver caused another car to cross over the median.

Alcohol-related crash results show some differences from the overall median crossover crash total. The primary cause of alcohol-related median crossover crashes was lost control on dry pavement (62.3 percent), whereas lost control and weather were similar percentages (41.7 percent and 44.0 percent, respectively) for the overall median crossover crash total. In alcohol related crashes, lost control is over three times as likely to be the initial cause of the crash (62.3 percent versus 18.8 percent). This may be due to the impaired abilities and lack of attention exhibited by a potentially impaired driver, so the probability of a lost control on dry pavement median crossover crash would likely increase even if the probability of a weather median crossover crash remained constant. The other noticeable difference in alcohol-related median crossover crashes as opposed to the overall crossover crash total is the age of the driver. Significantly more alcohol related median crossover crashes were found to occur with younger drivers, both in the under 25 population (47.8 percent versus 34.9 percent) and in the under 35 population (73.9 percent versus 55.8 percent).

The median crossover crash vehicle type for alcohol-related crashes showed a slightly higher percentage of single vehicle type median crossover crashes (89.9 percent versus 81.0 percent) as opposed to the overall crossover crash total. Crash severity was similarly distributed in alcohol-related crashes as in the overall crash total, with only a slight increase (10.1 percent versus 6.5 percent) in the amount of fatal crashes.

Mapping Median Crossover Crashes

Median crossover crash locations were mapped using GIS coordinates to more easily identify “hotspots,” i.e., locations where a significantly high amount of crashes are occurring in close proximity to one another. All 631 median crossover crashes were plotted on the Wisconsin state highway network, illustrated in Figure 52. Figures 53 through 55 present the median crossover crashes for each year analyzed.

Examination of the map reveals several counties where crash frequency clusters have formed. Two of these spots are quite apparent: I-39/I-90/I-94 in Dane and Columbia Counties and USH 41 in Fond du Lac and Winnebago Counties. Using the median barrier warrant criteria of 0.5 median crossover crashes per mile per year for at least three years of a five year period, Figure 56 presents the crossover crashes that meet the median barrier requirement. Counties highlighted in Figure 56 are presented in Appendix A.

As only three years of data was available, it is of interest to note what sites exceed more than 0.5 crashes per mile per year for only one or two out of three years. Each of these sites could potentially meet the three out of five year standard. Figures 57 and 58 display the sites identified.

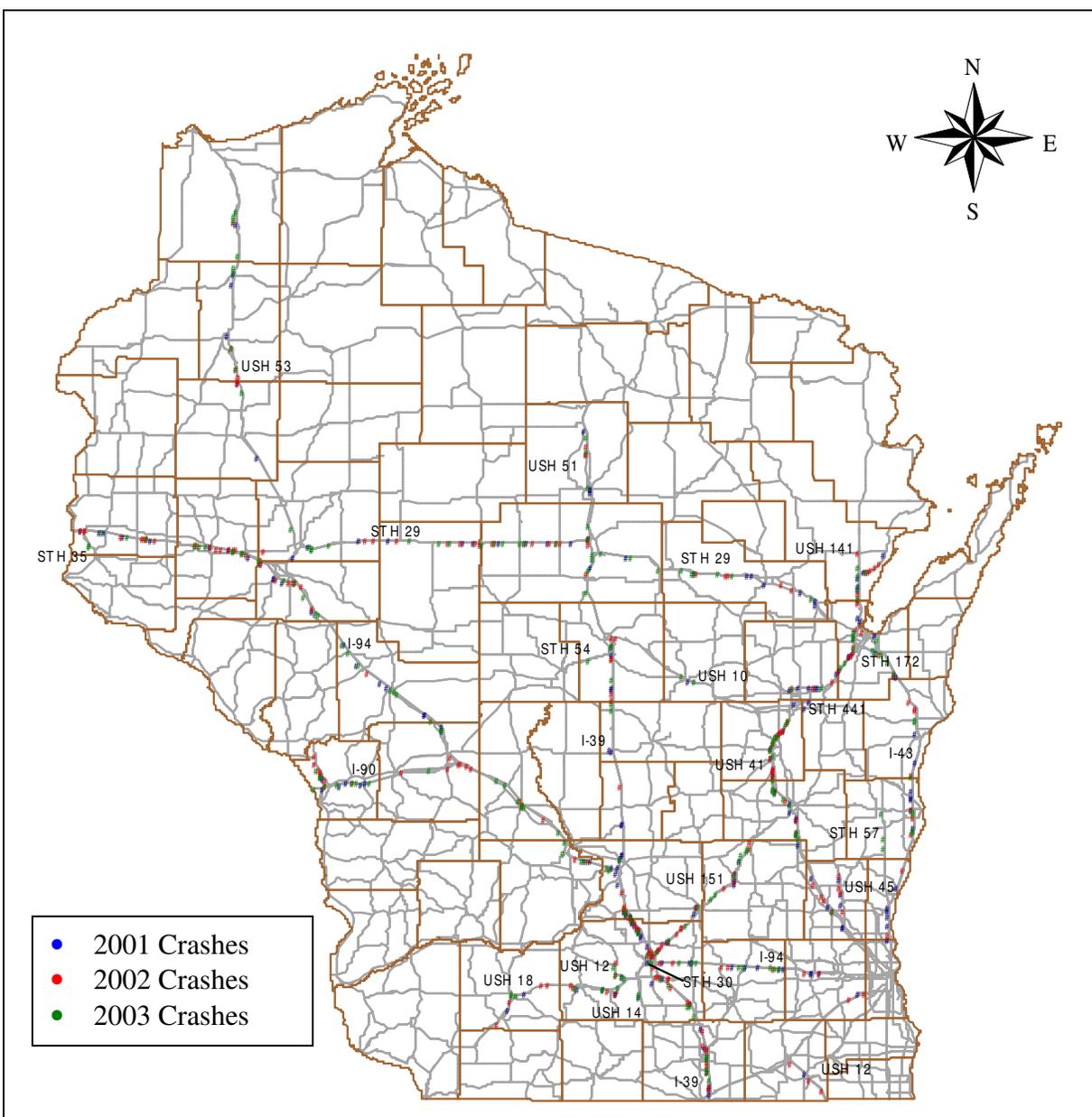


FIGURE 52 Median Crossover Crashes (2001 – 2003).



FIGURE 53 2001 Median Crossover Crashes.



FIGURE 54 2002 Median Crossover Crashes.

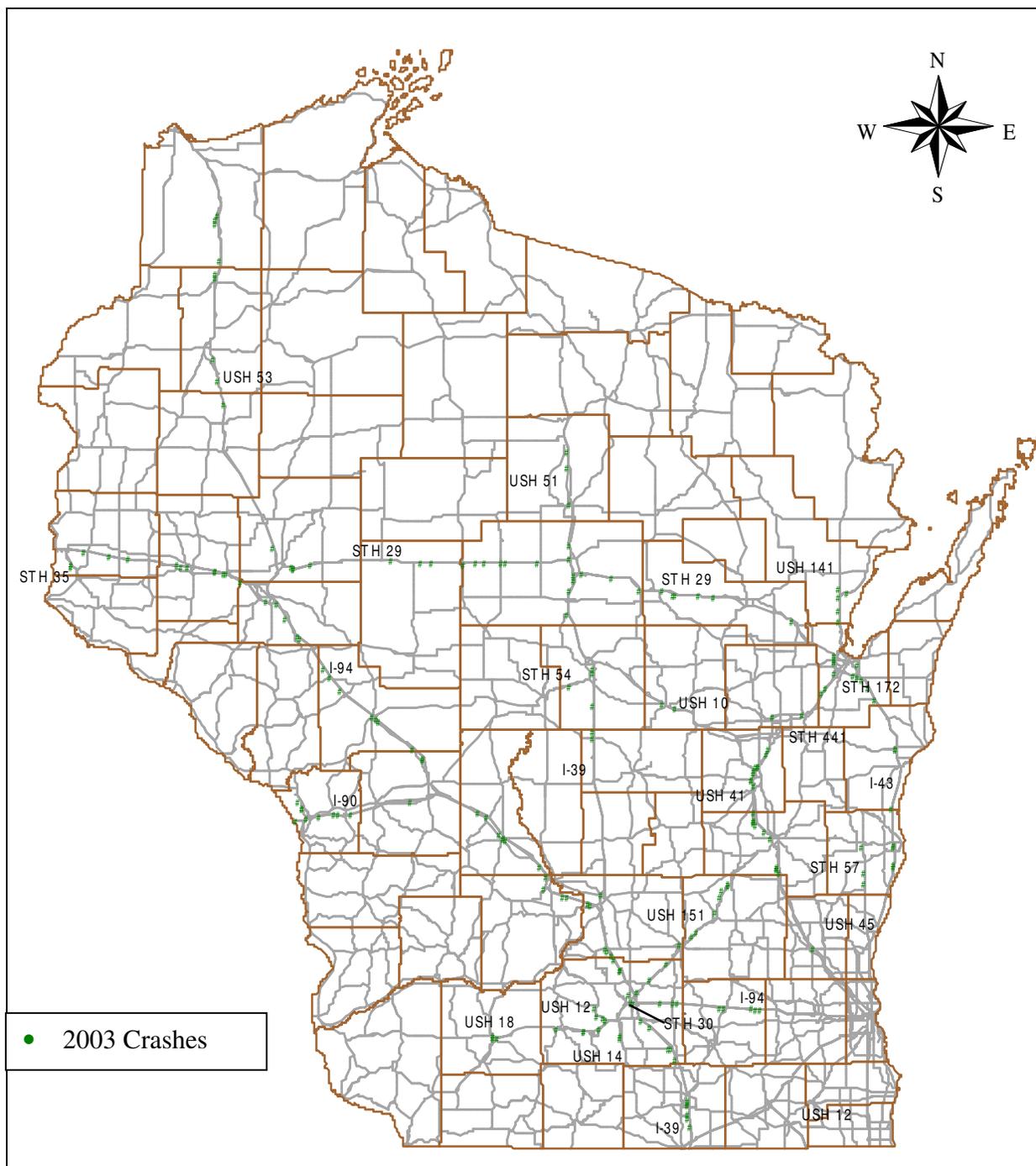


FIGURE 55 2003 Median Crossover Crashes.

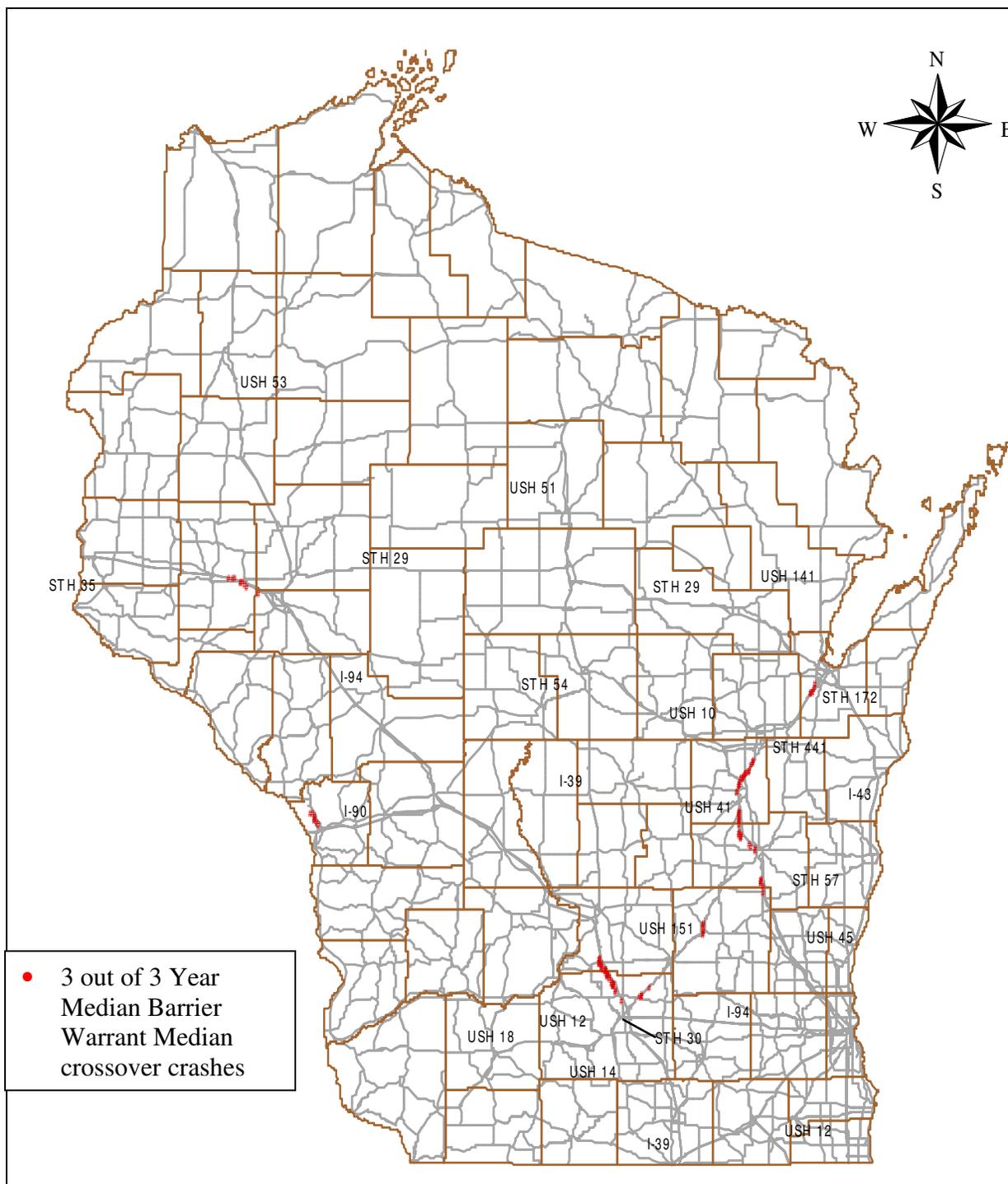


FIGURE 56 Median Barrier Warranted Median Crossover Crashes (3 Out Of 3 Years).

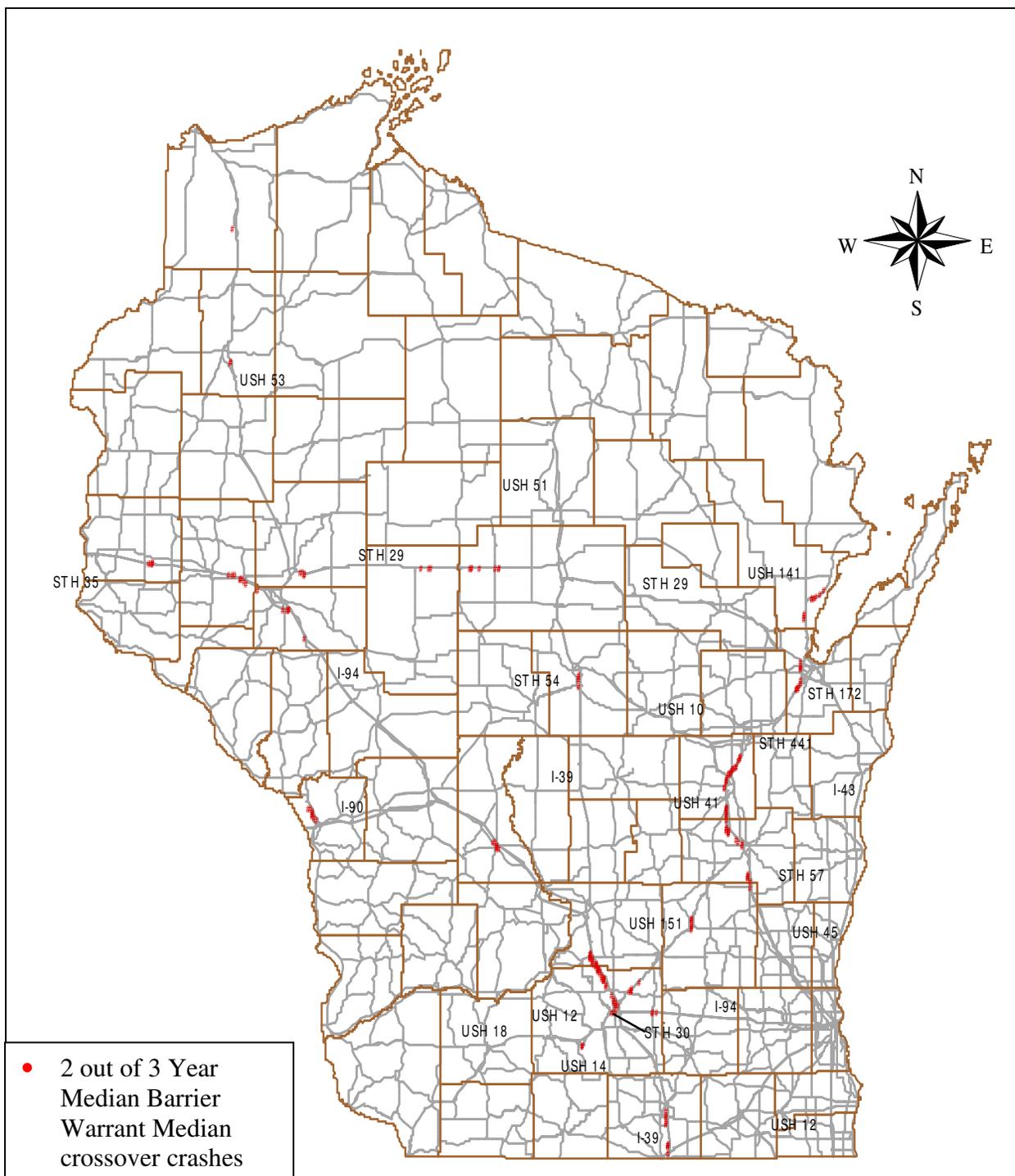


FIGURE 57 Median Barrier Warranted Median Crossover Crashes (2 Out Of 3 Years).



FIGURE 58 Median Barrier Warranted Median Crossover Crashes (1 Out Of 3 Years).

Median Crossover Crash Sites

A final variable considered involved a visual review of the WisDOT Photo Log, conducted to obtain graphical information of the median geometrics at selected median crossover crash sites. The locations selected were chosen from the median barrier warranted median crossover crashes. Table 32 lists the figures and description of each location. Photographs were obtained at:

- I-39/I-90/I-94 in Dane and Columbia Counties;
- I-94 in Dunn County;
- USH 41 in Fond Du Lac, Winnebago, and Brown Counties;
- USH 53 in La Crosse County; and
- USH 151 in Dane and Dodge Counties.

TABLE 32 Photo Log Median Crossover Crash Sites

Figure	Highway	County	City/Town	Median Width	Highway Feature
59	I-39/I-90/I-94	Dane	Windsor	38	Straight
60	I-39/I-90/I-94	Columbia	Arlington	60	Straight
61	I-94	Dunn	Elk Mound	50	Straight
62	USH 41	Fond Du Lac	Byron	50	Straight
63	USH 41	Winnebago	Oshkosh	50	Straight
64	USH 41	Brown	Ashwaubenon	60	Straight
65	USH 53	La Crosse	Onalaska	50	Slight Curve
66	USH 151	Dane	Bristol	60	Slight Curve
67	USH 151	Dodge	Beaver Dam	60	Straight



FIGURE 59 I-39/I-90/I-94 Dane County.



FIGURE 60 I-39/I-90/I-94 Columbia County.



FIGURE 61 I-94 Dunn County.



FIGURE 62 USH 41 Fond Du Lac County.



FIGURE 63 USH 41 Winnebago County.



FIGURE 64 USH 41 Brown County.



FIGURE 65 USH 53 La Crosse County.



FIGURE 66 USH 151 Dane County.



FIGURE 67 USH 151 Dodge County.

CHAPTER V COST OF MEDIAN CROSSOVER CRASHES

Crash severity, and the approximate corresponding costs associated with each crash, is another method that can be used to help determine the total costs of median crossover crashes. Similar to Macedo's results presented in Table 4, crash severity cost data were obtained for each median crossover crash. Crashes were grouped into three categories based on crash severity: property damage only, personal injury, and fatal. Though three different levels of personal injury exist in the KABCO ranking scale, the specific nature of the injuries for each crash was unavailable. Crash costs, obtained from NHTSA, are calculated using the maximum abbreviated injury scale (MAIS) which calculates personal injury into six different categories, 0 through 5 (24). Based on percentages used by Rothenberg with Massachusetts crash data, a range of costs was able to be calculated, depending on whether injuries were of severity level A, B, or C (40). Table 33 presents the cost breakdown of the select median crossover crashes. Weighting the costs by the amount of total crashes for each severity was used to calculate an average median crossover crash cost.

The wide range of the average cost of a median crossover crash reveals the importance to understand each injury sustained by a victim. Future availability of specific KABCO injury data for each crash will allow for a more definite average cost per median crossover crash.

The Center for Health Systems Research and Analysis (CHSRA) at University of Wisconsin-Madison houses the Wisconsin Crash Outcome Data Evaluation System (CODES) project. The CODES linkage project uses data from WisDOT and the Department of Health and Family Services to determine the cost associated with crashes that result in necessary medical treatment for the crash participants. Using these state-specific data, a medical cost for crashes can be determined. Since not all injured persons are hospitalized, there was a need to supplemental these costs with the national model to understand the total cost for crashes. The national model was available through the National Highway Traffic Safety Administration (NHTSA) in the Motor Vehicle Safety (MVS) software package. The MVS Software converts injury severity from the crash report form to maximum abbreviated injury score (MAIS) using nationally representative data.

TABLE 33 Average Cost of Median Crossover Crashes

Crash Severity	Comprehensive Crash Cost (\$)	Proportion of Crashes	Weighted Cost (\$)
Fatal (K)	3,366,000	6.50	218,790
Personal Injury Range		53.25	1,065 – 476,055
<i>Serious Injury (A)</i>	<i>894,000</i>		<i>476,055</i>
<i>Minor Injury (B)</i>	<i>68,000</i>		<i>36,210</i>
<i>No Visible Injury (C)</i>	<i>2,000</i>		<i>1,065</i>
Property Damage Only (O)	2,500	40.25	1006
Weighted Average Median Crossover Crash Cost Range			220,861 – 695,851

From this conversion, medical and other economic costs can be estimated by MAIS, property damage only, or fatality cases. MVS includes a wide range of costs relating to a crash including medical, emergency service, market productivity lost, household productivity lost, insurance administration, workplace, legal, travel delay, and property damage costs. Based on this initial estimate, CODES costs, which are directly associated with the medical diagnosis codes and injury severity, are then used to adjust the overall crash cost. Both the CODES data along with the MVS software data can be used to better control for more serious injuries which may be associated with either the crossover crashes identified in this research or the associated control group of median barrier impact crashes.

The median crossover accident numbers were provided for the CODES analysis. Only 2001 and 2002 crash data was used to coincide with the available CODES data. In performing benefit/cost analysis for median crossover crashes, the benefit from the reduction in median crossover crashes must be compared to barrier installation and maintenance costs as well any increase in median-barrier crashes that would be created (39). A comparison group, consisting of crashes involving median barrier hits, was used to estimate costs of median barrier crashes versus crossover crashes. The comparison crashes were selected based on the following criteria:

1. Were on a roadways with a 65 mph speed limit;
2. Involved a collision with a guardrail or a median barrier; and
3. Collision involved the driver side (left side) of the vehicle.

The comparison group was not analyzed by the Traffic Operations and Safety (TOPS) Lab researcher staff.

Table 34 provides the results of the CODES analysis for median crossover crashes. Note that both median entry only and median crossover crashes were considered in the analysis. Table 35 presents the results of the CODES analysis for the comparison group and the differences between median crossover crashes and the comparison group. Only the median crossover crashes versus the comparison group are discussed hereafter.

Eight percent of the crossover occupants (82 out of 966) were hospitalized compared to two percent of the control group. The average hospital cost for the median crossover occupants was approximately \$225,000 while the comparison group was approximately \$153,000. Note that the costs are associated with a person, thus occupant numbers were used rather than crashes. In the comparison group, there were a total of 3,117 occupants involved in those crashes for 2001 and 2002. Sixty-four of the 3,117 occupants were linked to hospital data files. Only two percent of the occupants were hospitalized with an average cost of almost \$153,000. The rest of the occupant costs were determined using the NHTSA MVS Model. The comparison group cost \$86,206,514 for the two years for all occupants. This results in a cost of \$27,657 per comparison group occupant for 2001 and 2002.

There were 966 occupants in the median crossover crashes for 2001 and 2002. Eight percent of the occupants (82 out of 966) were hospitalized with an average cost of almost \$225,000. The median crossover occupants cost was \$64,513,724 for the two years for all occupants which is \$66,784 per crossover occupant for 2001 and 2002. CHSRA provided the cost difference

between the occupants involved in a median crossover crash compared to those involved in a comparison crash. The cost difference between median crossover crashes and comparison crashes was \$39,128 per occupant. For the two years, median crossover crashes cost \$37,797,172 more than the comparison group from this analysis.

From the findings of the CHSRA analysis, median crossover crashes result in a higher percentage of occupants being hospitalized (eight versus two percent) and higher cost for hospitalization and all injury severities. Average hospital cost was approximately \$72,000 more for the median crossover occupants. Examining both hospitalized and non-hospitalized occupants, median crossover occupants cost approximately \$39,000 more than the comparison group. Crashes that occur when vehicles strike a median barrier or guardrail are less costly than crashes that crossover the median. The cost of crashes with median barriers were approximately \$19 million less in medical costs on an annual basis than median crossover data, considering the data set evaluated.

TABLE 34 Estimates of Costs of Median Crossover Crashes and Median Entry Crashes

Type of Model	Population	Total Estimated Costs	Number of Cases	Per Case Cost (\$)
ALL CASES: CROSSOVER AND MEDIAN CASES COMBINED				
NHTSA MVS Model Only	Crossover Crashes	164,097,100	4,596	35,704
MIXED MODEL ESTIMATES				
Diagnostic Group Model (Hospitalized Cases Only)	Crossover Crashes	36,523,401	183	199,581
<u>NHTSA MVS Model Only (Adjusted)</u>	<u>Crossover Crashes</u>	<u>150,013,000</u>	<u>4,413</u>	<u>33,993</u>
Total -- Mixed Model		186,536,401	4,596	40,587
Percent Change in Per Unit Costs (mvs VS Mixed)	Crossover Crashes	13.7%		
ALL CASES: CROSSOVER ONLY CASES				
NHTSA MVS Model Only	Crossover Crashes	52,902,100	966	54,764
MIXED MODEL ESTIMATES				
Diagnostic Group Model (Hospitalized Cases Only)	Crossover Crashes	18,437,524	82	224,848
<u>NHTSA MVS Model Only (Adjusted)</u>	<u>Crossover Crashes</u>	<u>46,076,200</u>	<u>884</u>	<u>52,122</u>
Total -- Mixed Model		64,513,724	966	66,784
Percent Change in Per Unit Costs (mvs VS Mixed)	Crossover Crashes	21.9%		
ALL CASES: MEDIAN ONLY CASES				
NHTSA MVS Model Only	Crossover Crashes	111,196,100	3,630	30,633
MIXED MODEL ESTIMATES				
Diagnostic Group Model (Hospitalized Cases Only)	Crossover Crashes	18,085,875	101	179,068
<u>NHTSA MVS Model Only (Adjusted)</u>	<u>Crossover Crashes</u>	<u>103,936,700</u>	<u>3,529</u>	<u>29,452</u>
Total -- Mixed Model		122,022,575	3,630	33,615
Percent Change in Per Unit Costs (mvs VS Mixed)	Crossover Crashes	9.7%		

Table 35 Estimates of Cost Differentials Between Vehicles Involved in Crossover Crashes Versus Vehicles Striking a Median Barrier or Guardrail

COMPARISON GROUP ONLY	Population	Total Estimated Costs (\$)	Number of Cases	Per Case Cost (\$)
NHTSA MVS Model Only	Comparison Group	\$ 80,209,693	3117	25,733
MIXED MODEL ESTIMATES				
Diagnostic Group Model (Hospitalized Cases Only)	Comparison Group	\$ 9,797,724	64	153,089
<u>NHTSA MVS Model Only (Adjusted)</u>	<u>Comparison Group</u>	\$ 76,408,790	3053	<u>25,027</u>
Total -- Mixed Model		\$ 86,206,514	3,117	27,657
Percent Change in Per Unit Costs	Comparison Group	7.5%		
		Total Biannual Costs (\$)	Number of Occupants	Per Occupant Costs (\$)
Cost Difference Between ALL Crashes and Comparison Group		59,425,352	4,596	12,930
Cost Difference Between CROSSOVER ONLY Crashes and Comparison Group		37,797,172	966	39,128
Cost Difference Between MEDIAN ONLY Crashes and Comparison Group		21,628,078	3,630	5,958

CHAPTER VI CONCLUSIONS & RECOMMENDATIONS

Median crossover crashes are a concern for transportation officials across the country. The nature of a median crossover crash – a vehicle traversing a median of a divided roadway and potentially hitting another vehicle either head-on or side-swipe – creates a situation that is high cost, both financially and in terms of human injury. The magnitude of median crossover crashes in Wisconsin was unknown, including the characteristics and causes of these crashes.

Median barriers are installed on Wisconsin highways that meet a certain median width/ADT requirement. A median width of 60 feet is the Wisconsin standard non-barrier median width for highways with a speed limit greater than 55 mph. Nevertheless, median crossover crashes have been observed on 50 foot and 60 foot medians that do not meet the current warrants for median barrier protection. There was a need in Wisconsin to identify how many median crossover crashes were occurring, at what locations, and if the standards for median width and median barrier warrants needed to be re-evaluated. The objective of this research was to evaluate median crossover crashes in Wisconsin, determine the relationship between the crashes and median width, and quantify the costs of median crossover crashes to establish benefit/cost ratios between the crashes occurring and potential safety improvements. It was hypothesized that there are a significant number of median crossover crashes in Wisconsin and also that as median widths increased, median crossover crashes would decrease.

Crash reports for Wisconsin highways were reviewed to quantify median crossover crashes. Median width and ADT data for each selected crash site was analyzed to determine any potential correlation between median crossover crashes and median width. Data from each selected crash report were analyzed to determine common characteristics and significant factors affecting the likelihood of a median crossover crash. Statistical analysis was completed on the data to determine which factors would most likely affect a median crossover crash and which factors would most likely increase the severity of a median crossover crash. CODES analysis was performed on the selected crashes to help establish a benefit/cost ratio for median crossover crashes compared to similar crashes that involved a median barrier. All this data will be used to establish models that can be used to identify sites that should be reviewed for potential media safety improvements, even if current standards do not deem a median barrier necessary.

CONCLUSIONS

After completing the study and analysis of median crossover crashes, the following conclusions were made:

Median Crossover Crashes and Median Width

Hypothesis 1

- *Median crossover crashes are a significant problem for the state of Wisconsin.* Six hundred thirty-one median crossover crashes were found over a three year period, resulting in over 600 injuries and 53 fatalities. The magnitude of median crossover crashes, an average of 210 per year, indicates that this crash type is indeed a problem in Wisconsin. Six roadway segments in Wisconsin exceeded the commonly used

benchmark of 0.5 crashes/mile/year in all three years analyzed. One site exceeded the 0.12 fatalities/mile/year benchmark for all three years analyzed.

Hypothesis 2

- *Median crossover crashes and median width are not strongly correlated with each other.* Median crossover crashes adjusted by vehicle miles traveled related to the median width showed a very slight decrease in median crossover crashes as median width increased. However, the trend line is nearly flat and the coefficient of determination quite small suggesting that there is no significant relationship between the median width and the median crossover crash rate. The data are in fact almost a true scatter plot, with narrow median and large median segments each having low and high crash rates. Therefore, there does not appear to be a combination of ADT and median widths that lead to higher frequencies of median crossover crashes.

These results suggest that the current median barrier standards in the state of Wisconsin should be re-evaluated. Approximately 82 percent of the selected median crossover crashes occurred on roadways with median widths that did not warrant a median barrier. Of these crashes, many occurred on roadways with typical median widths of 50 or 60 feet and common cross-slopes.

Several other significant findings can be summarized:

Median Crossover Crash Severity

- Most median crossover crashes involved either personal injury or a fatality. Personal injury crashes accounted for 53 percent of median crossover crashes, while 7 percent of median crossover crashes involved a fatality.
- The risk of a more serious crash increased as the amount of vehicles involved in a crash increased. Property damage only crashes decreased from 44 percent of all single vehicle median crossover crashes to only 19 percent of all three-vehicle crashes. Fatal crashes increased from 3 percent of all single vehicle median crossover crashes to 19 percent of all three-vehicle crossover crashes.
- The risk of a more serious crash is greatly increased if there is a collision between vehicles from opposing roadways. Single vehicle type median crossover crashes, those that did not involve a collision with a vehicle from the opposing roadway, accounted for 81 percent of all median crossover crashes. However, while 53 percent of single vehicle type crashes were personal injury crashes, only 1.3 percent involved a fatality. Conversely, 58 percent of multiple vehicles type median crossover crashes, those that did involve a collision with a vehicle from the opposing roadway, were personal injury crashes and 24 percent involved a fatality.

Median Crossover Crash Actions, Causes, and Crossover Extent

- Most median crossover crashes involved vehicles that were going straight on the roadway prior to the crash. Vehicles that were going straight accounted for 77 percent of the median crossover crashes. The next most common actions were changing lanes, 7.9

percent of the median crossover crashes, and negotiating a curve, 4.3 percent of the median crossover crashes.

- A majority of the median crossover crashes were the result of either a loss of control of a vehicle on dry pavement or loss of control of a vehicle due to weather. Loss of control on dry pavement was the initial causation for 42 percent of the median crossover crashes, while loss of control due to weather was the initial causation for 44 percent of the median crossover crashes. Vehicle collision was the initial causation for 11 percent of median crossover crashes.
- Of the 631 total median crossover crashes, 278 were related to weather. Winter weather road conditions were most directly responsible for loss of control due to weather. Ice was responsible for 42 percent of weather-related loss of control crashes, while snow accounted for 33 percent of weather-related loss of control crashes. Wet roadways only were the cause of 24 percent of weather-related loss of control crashes. The five month period of December to April accounts for 76 percent of weather-related loss of control crashes. Loss of control on dry pavement crashes are more evenly distributed, with the largest five month period, April through August, containing only 46 percent of the total amount of loss of control on dry pavement crossover crashes. Weather was also identified as a significant variable leading to median crossover crashes in the statistical analysis.
- Lost control due to weather crashes resulted in fewer serious injury crashes than loss of control on dry pavement crashes. Weather-related loss of control median crossover crashes accounted for 50 percent of all property damage only crashes, 42 percent of personal injury crashes, and 32 percent of fatal crashes. Conversely, lost control on dry pavement was the initial causation for 36 percent of property damage only crashes, 44 percent of personal injury crashes, and 61 percent of fatal crashes.
- The most common extent of median crossover was into the opposing roadway, which accounted for 39 percent of the selected median crossover crashes. Median crossover vehicles that made it partially onto the opposing roadway made up 26 percent of the crash total while vehicles that crossed over beyond the extent of the opposing roadway made up 33 percent of the crash total.
- Single vehicle type median crossover crashes, while comprising 81 percent of all median crossover crashes, accounted for 90 percent of median crossover crashes that went beyond the extent of the opposing roadway and 98 percent all median crossover crashes that made it partially onto the opposing roadway. Most multiple vehicles type crashes, 79 percent, were crashes where a vehicle crossed the median and landed in the opposing roadway.
- Multiple vehicle crashes increase as the ADT of the roadway increases. Property damage only and personal injury crashes are fairly evenly distributed among the different crossing over extent. However, 75 percent of fatal median crossover crashes involved crossover vehicles that came to rest in the opposing roadway.

Crash Demographics

- Median crossover crashes are more of a problem for younger drivers. Drivers under the age of 25 account for approximately twice as many median crossover crashes as does any other age bracket. Drivers under the age of 25 were involved in 35 percent of all median crossover crashes.
- Alcohol was a factor in 11 percent of the median crossover crashes. A majority of alcohol-related crossover crashes were caused by a loss of control on dry pavement, contributing to 62 percent of the alcohol-related median crossover crash total. Drivers under the age of 25 were responsible for 48 percent of all alcohol-related median crossover crashes. Personal injury crashes account for 52 percent of all alcohol-related median crossover crashes, while 10 percent of alcohol-related crossover crashes were fatal.

Fatal Crashes

- The most common cause of a fatality was an impact with an opposing direction vehicle. Impact with an opposing vehicle was the cause of 60 percent of all fatalities. Ejections were the cause of 28 percent of all fatalities, which further emphasizes the benefit of vehicle safety belts.

High Frequency Crash Locations

- Five sites were found that had crossover crash frequencies greater than the selected criteria of 0.5 crashes per mile per year for three years. This list of locations includes:
 - I-39/I-90/I-94 in Columbia and Dane Counties
 - I-94 in Dunn County
 - USH 41 in Fond Du Lac, Winnebago, and Brown Counties
 - USH 53 in La Crosse County
 - USH 151 in Dane and Dodge Counties
- One site was found to exceed the fatal crash criteria of 0.12 fatal crashes per mile per year. This location was at the I-39/I-90/I-94 site in Columbia and Dane Counties.

CODES Analysis

- The CODES analysis found that the cost of crossover crashes, in terms of medical costs, exceed median barrier impact crashes by approximately \$19 million per year (given the data set evaluated). Although the full cost of installing median barrier cannot be evaluated, it is apparent that the potential medical and societal cost savings of median barrier installation at high frequency crossover crash locations is significant.

RECOMMENDATIONS

Though substantial research has been presented here, there is still more work that can be done to investigate median crossover crashes and improve the safety of the roadways in Wisconsin. As with any research effort, for everything that is learned, there are other unanswered questions that develop requiring additional investigation. Data were limited in this project to only three years of crash reports, 2001 through 2003. An increase in the amount of years examined, if yielding similar results, would create greater support to the results found. The median barrier requirements of 0.5 median crossover crashes per mile per year and 0.12 fatal median crossover crashes per mile per year are based on a requirement of three out of five years. The crashes identified in Figures 37 and 53 are based on three out of three years, more stringent than the requirements indicate. With a five-year crash study, potentially more crash sites would be located that would be likely candidates for median safety improvements.

As stated in Hypothesis 2, one of the main objectives of this research was to determine the relationship between median crossover crash frequency, median width, and ADT. Though there was no strong direct relationship between median width and median crossover crash frequency, there are other confounding variables that have an effect on whether a median crossover crash occurs. Several of these variables, such as crash vehicle type, initial causation of crash, and age of driver have been documented in this research. Nevertheless, there are numerous ways that all these variables can interact to affect the crash. In addition, some variables, such as median cross slope, were unable to be examined for this research. The findings of this research in relation to median crossover crash frequency and median width are significant, but more study needs to be done to further substantiate the effects that other confounding variables have on median crossover crashes.

Specific recommendations based on the findings of this research include:

- Consider the installation of median barrier protection at the following locations:
 - I-39/I-90/I-94 in Columbia and Dane Counties
 - I-94 in Dunn County
 - USH 41 in Fond Du Lac, Winnebago, and Brown Counties
 - USH 53 in La Crosse County
 - USH 151 in Dane and Dodge Counties

Research should be conducted to evaluate the cost of installing the median barrier, the number of median barriers hits after installation, the maintenance cost of the median barrier, and the change in crash frequencies and CODES cost after installation.

- Reconsider the standard in the WisDOT Facilities Development Manual for warranting median barriers. The results of this research found that 81.5 percent of the median crossover crashes occurred in locations where median barriers were not warranted. Other states have found significant safety improvements by lowering the level of ADT and median width necessary to warrant median barrier.

- Gather additional median geometric data (cross-slope; material) on the locations included in this research. Additional query and analysis can be completed with these data. A comprehensive benefit/cost analysis can then be completed.
- Continue research and public awareness campaigns to help prevent median crossover crashes before they happen. This includes better education of drivers about the dangers of winter driving and better education of younger drivers in how to recover a vehicle in distress and prevent crossing into the opposing roadway. Continued education and reinforcement in the importance of seat belts could help reduce the severity to occupants involved in median crossover crashes.

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APPENDIX A

Median crossover crash County Maps for:

**Dane County
Columbia County
Dodge County
Fond Du Lac County
Winnebago County
Brown County
Dunn County
La Crosse County**

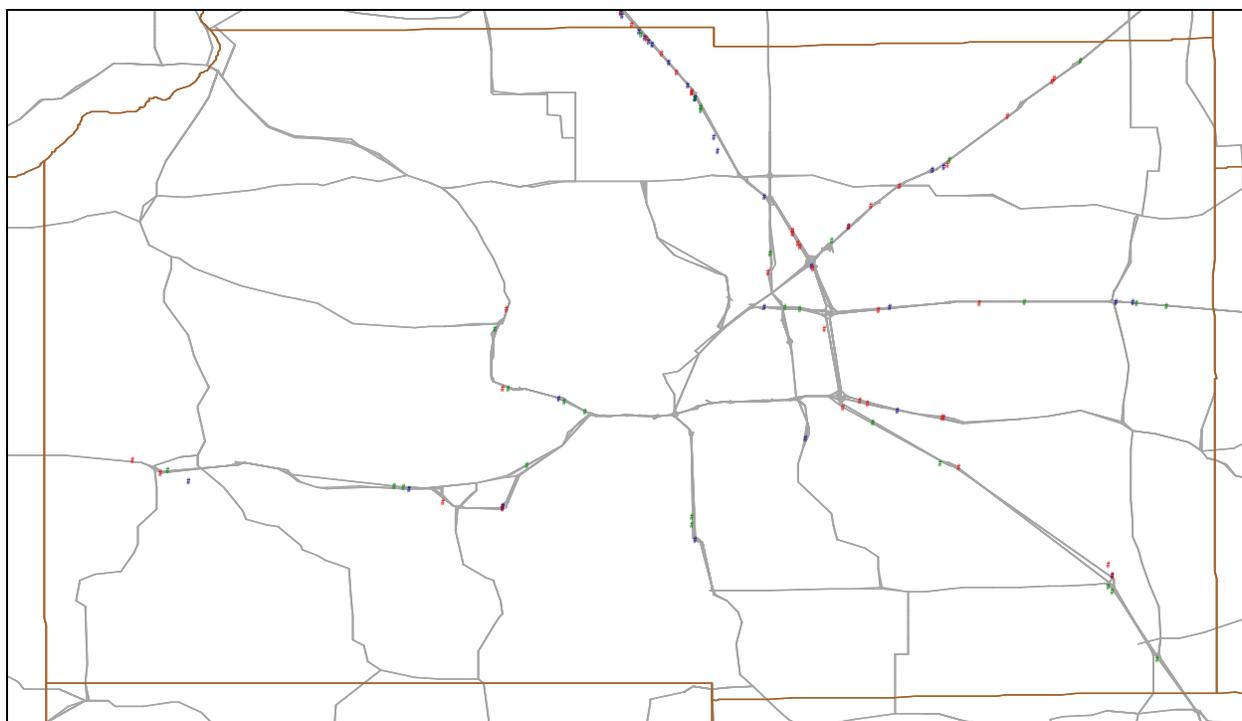


FIGURE A-1 Dane County Median Crossover Crashes (2001 – 2003).

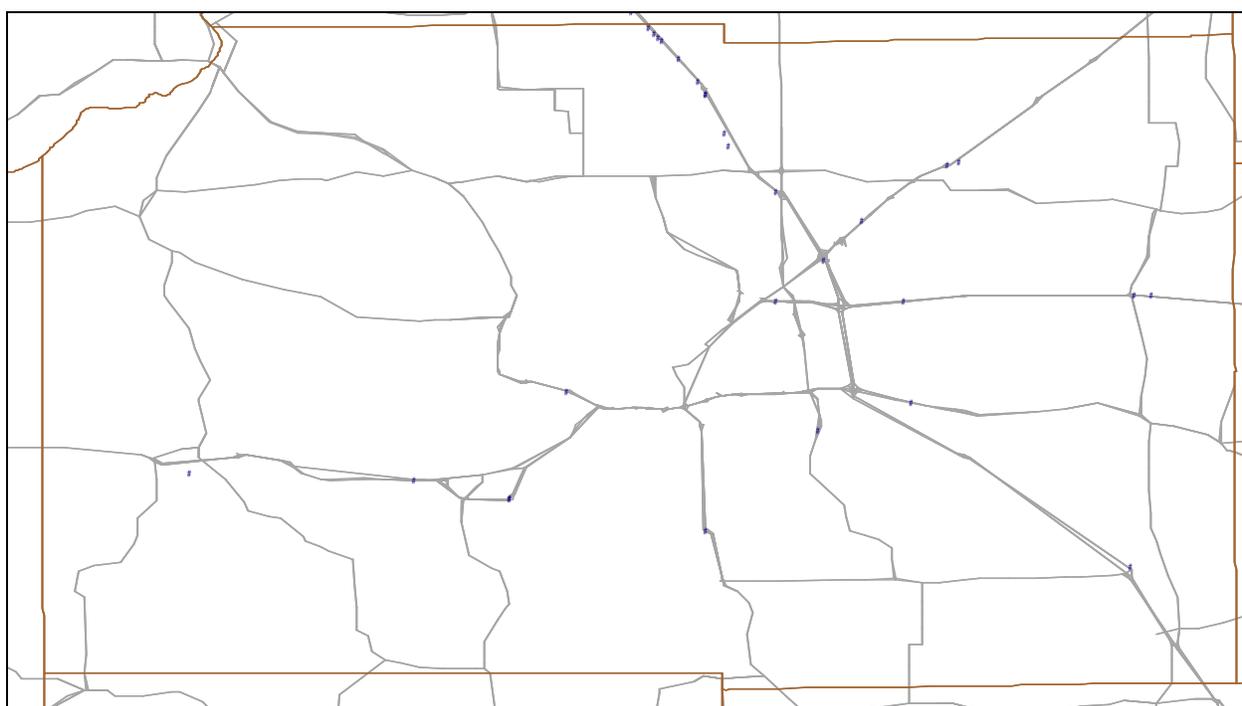


FIGURE A-2 2001 Dane County Median Crossover Crashes.

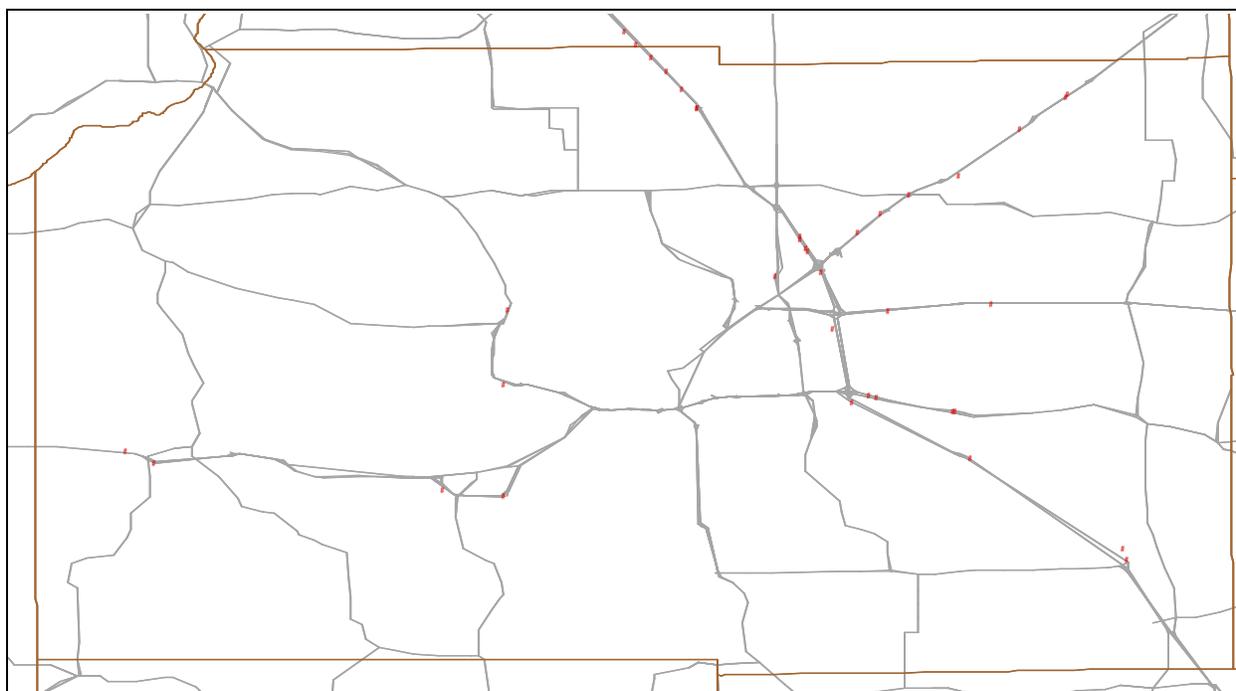


FIGURE A-3 2002 Dane County Median Crossover Crashes.

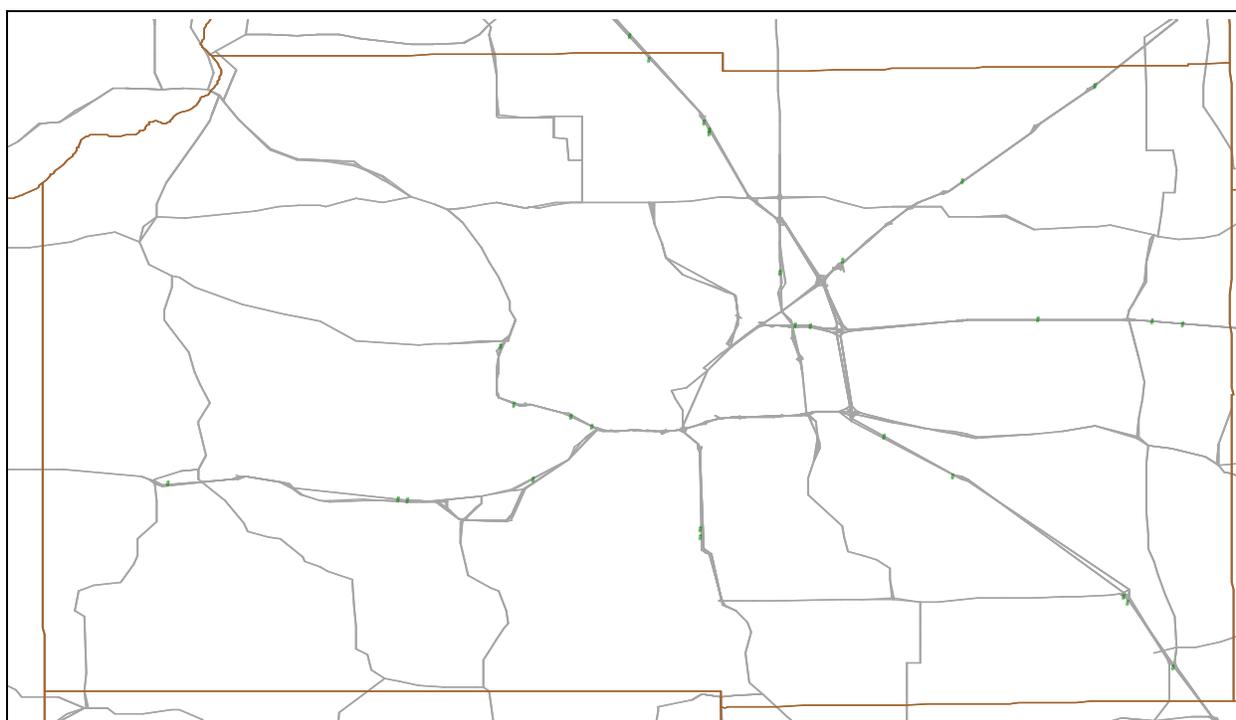


FIGURE A-4 2003 Dane County Median Crossover Crashes.

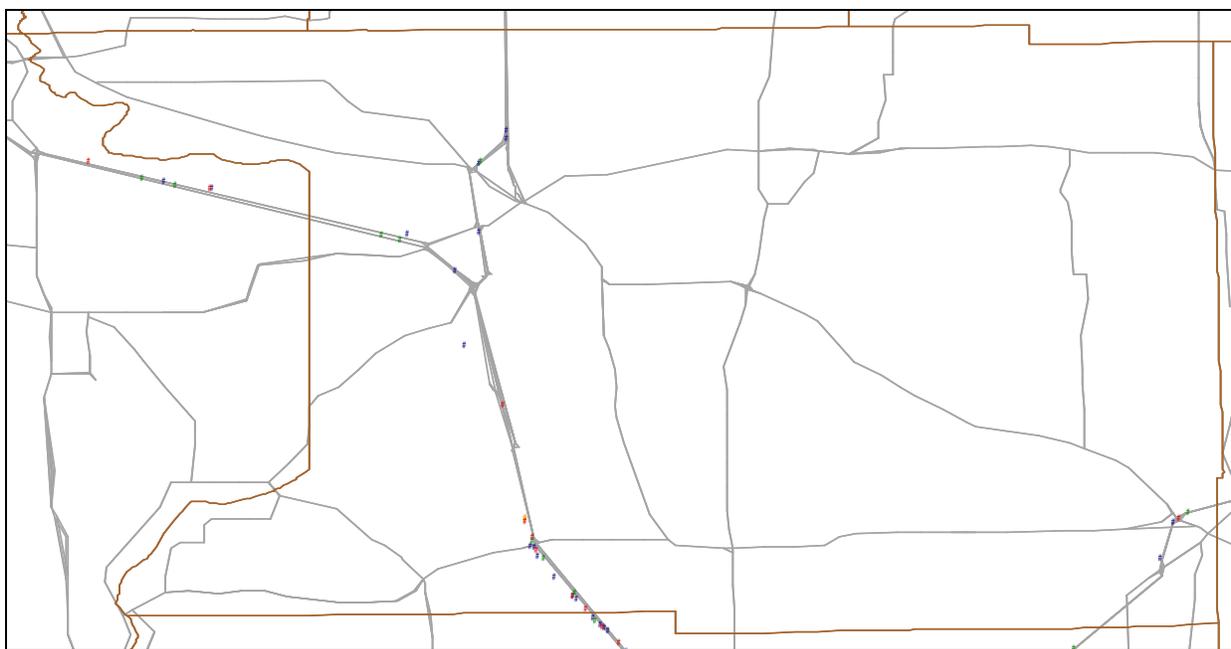


FIGURE A-5 Columbia County Median Crossover Crashes (2001 – 2003).

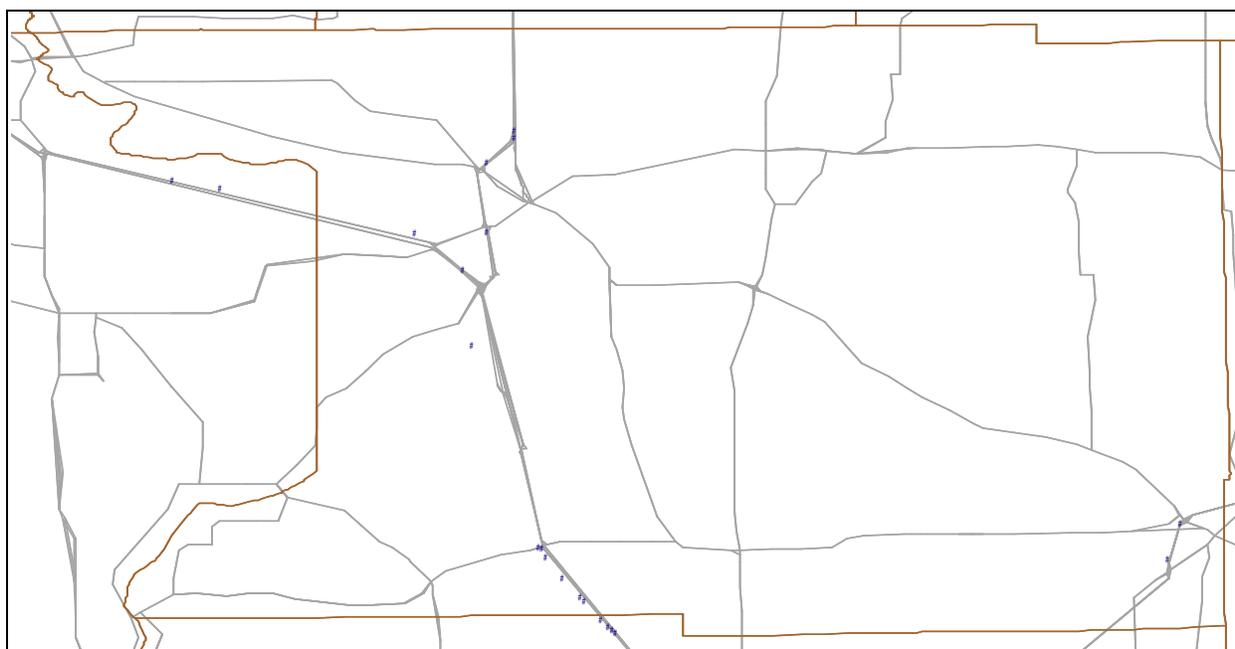


FIGURE A-6 2001 Columbia County Median Crossover Crashes.

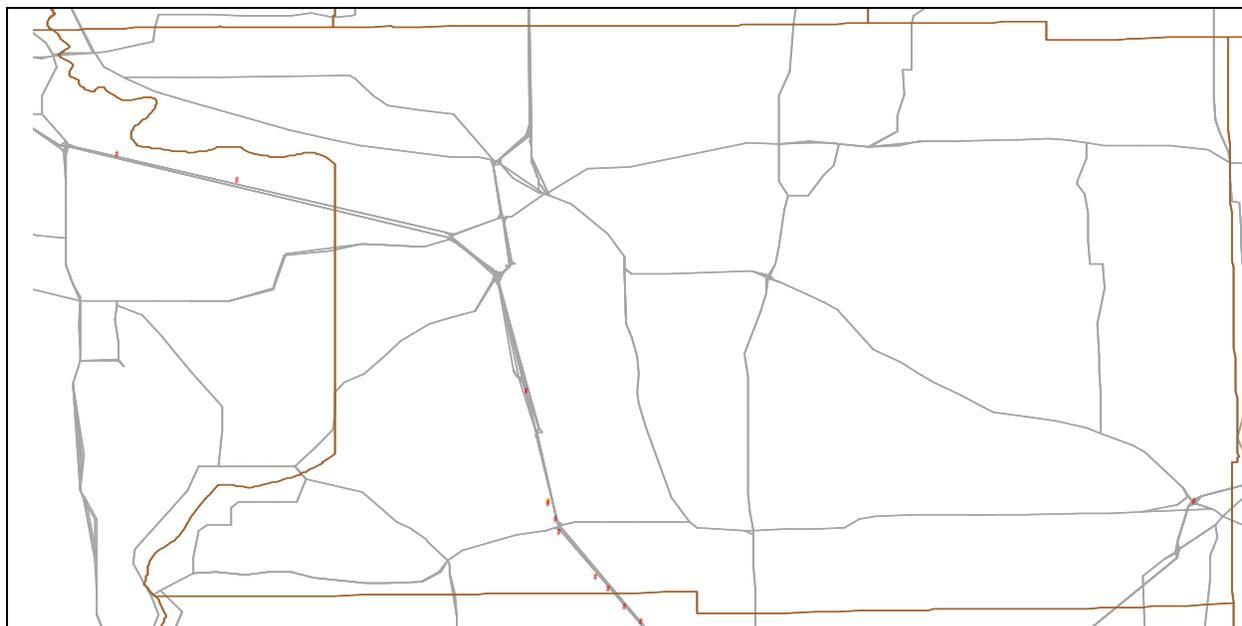


FIGURE A-7 2002 Columbia County Median Crossover Crashes.

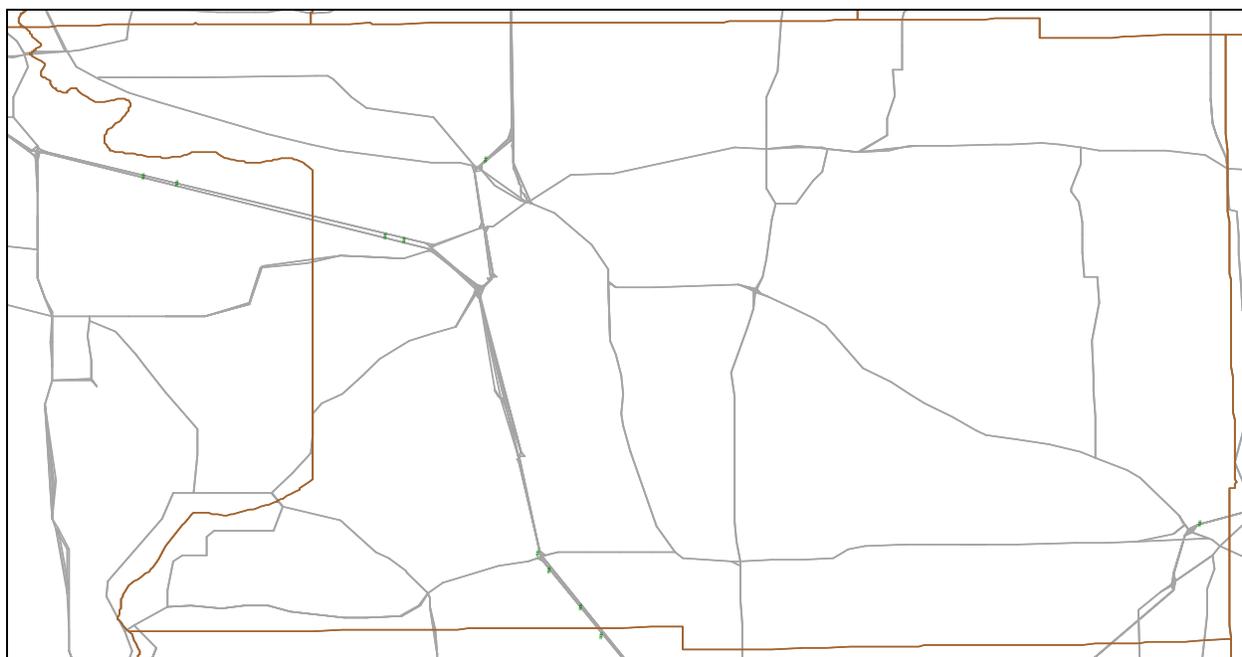


FIGURE A-8 2003 Columbia County Median Crossover Crashes.

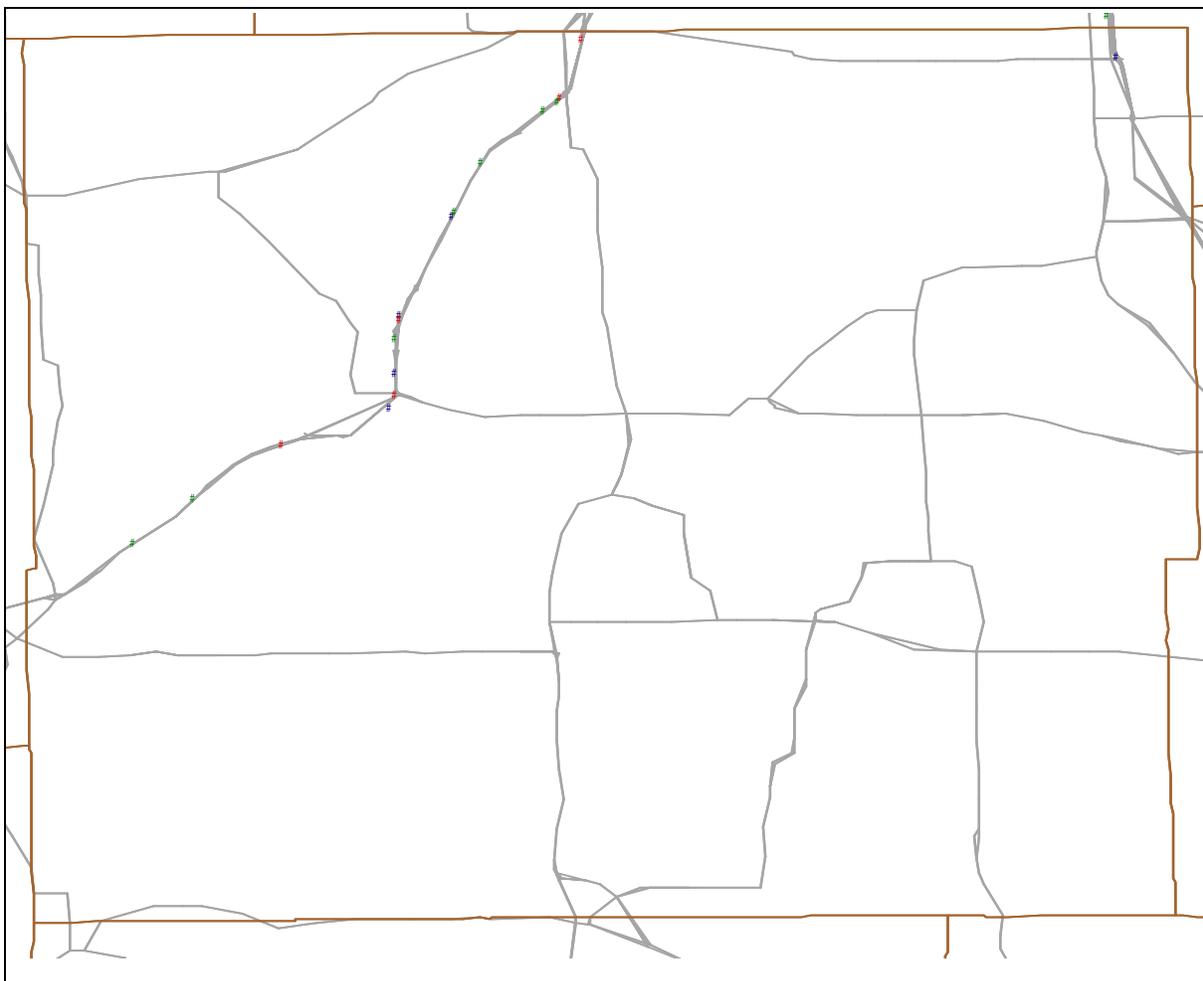


FIGURE A-9 Dodge County Median Crossover Crashes (2001 – 2003).

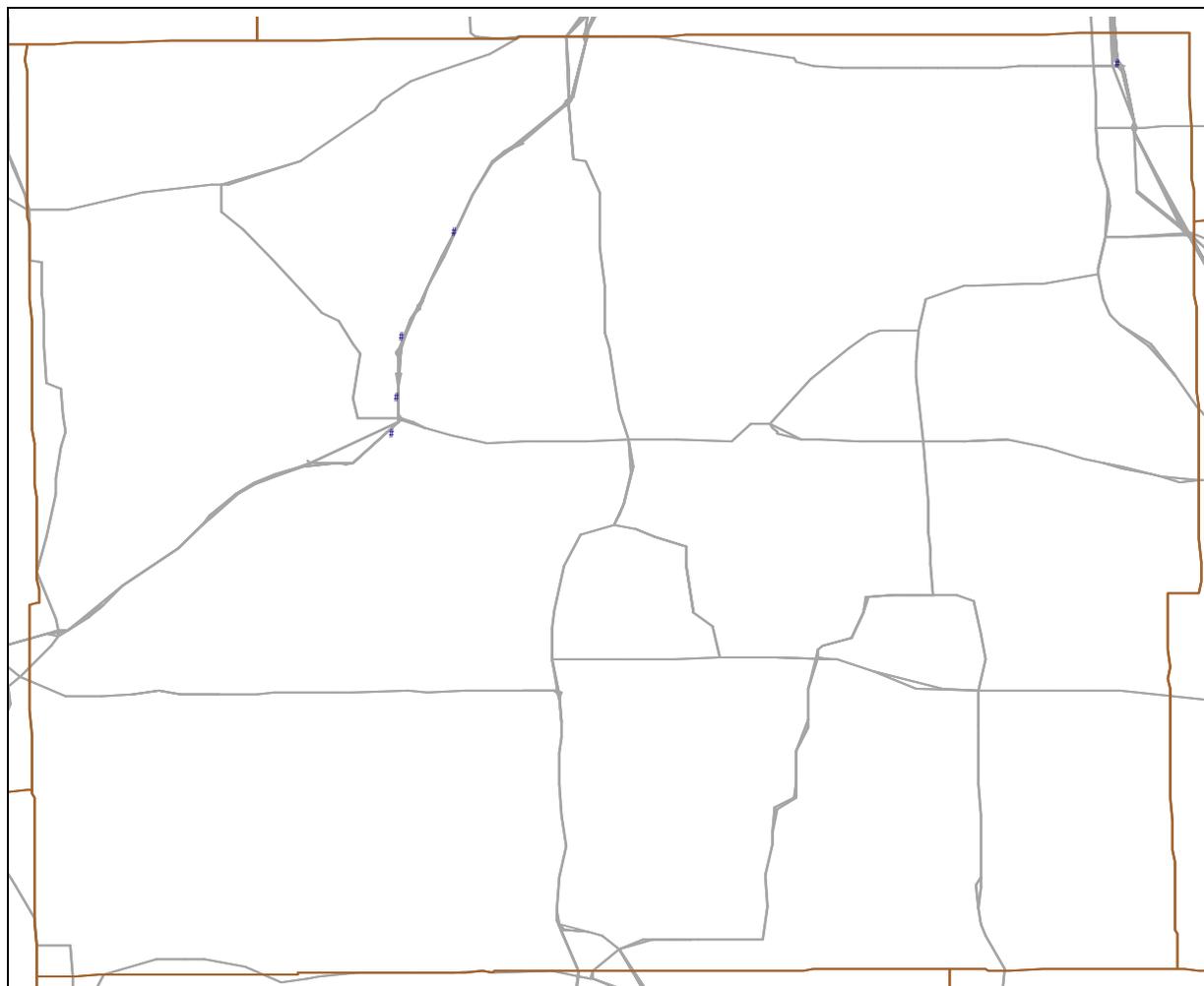


FIGURE A-10 2001 Dodge County Median Crossover Crashes.

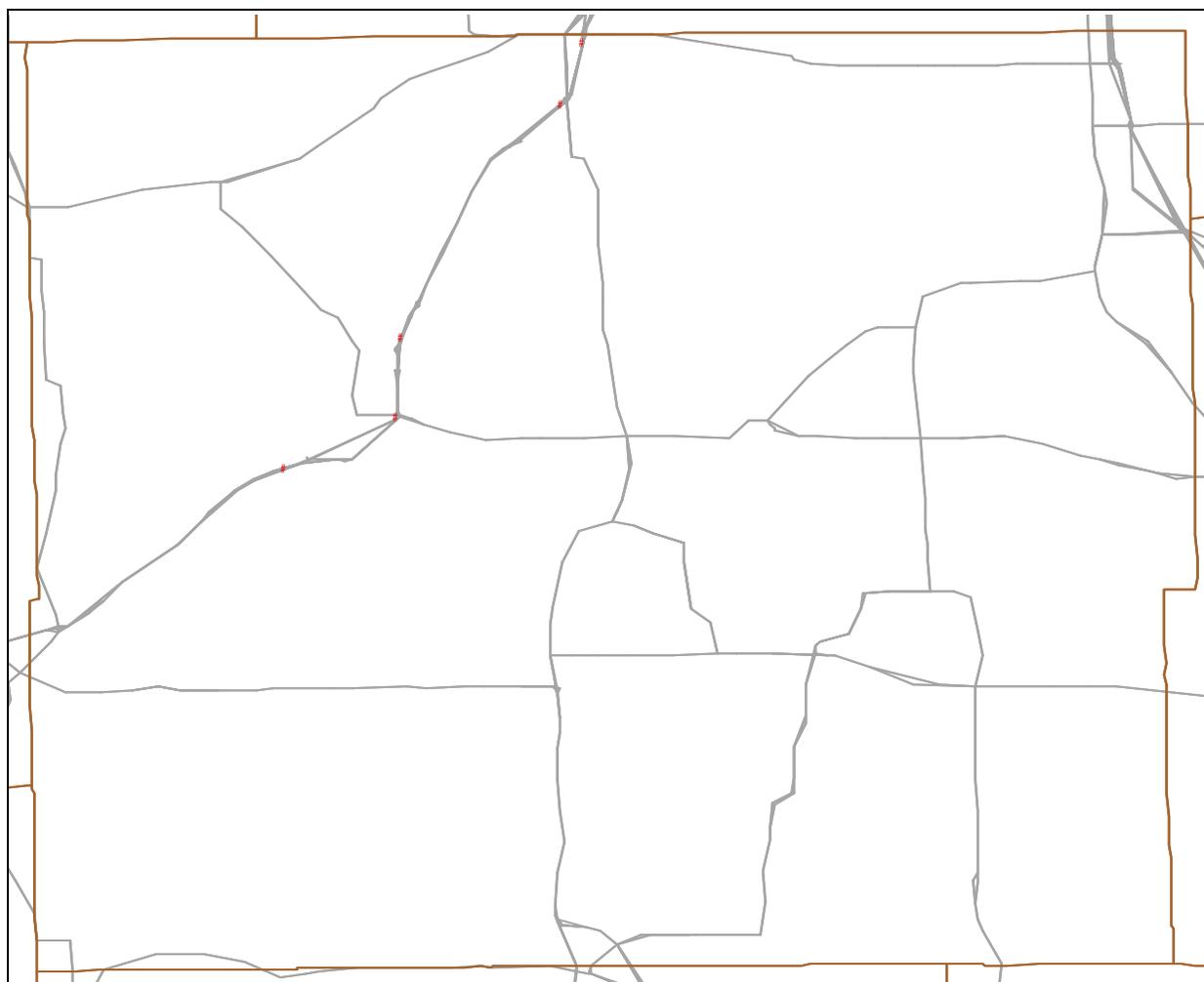


FIGURE A-11 2002 Dodge County Median Crossover Crashes.

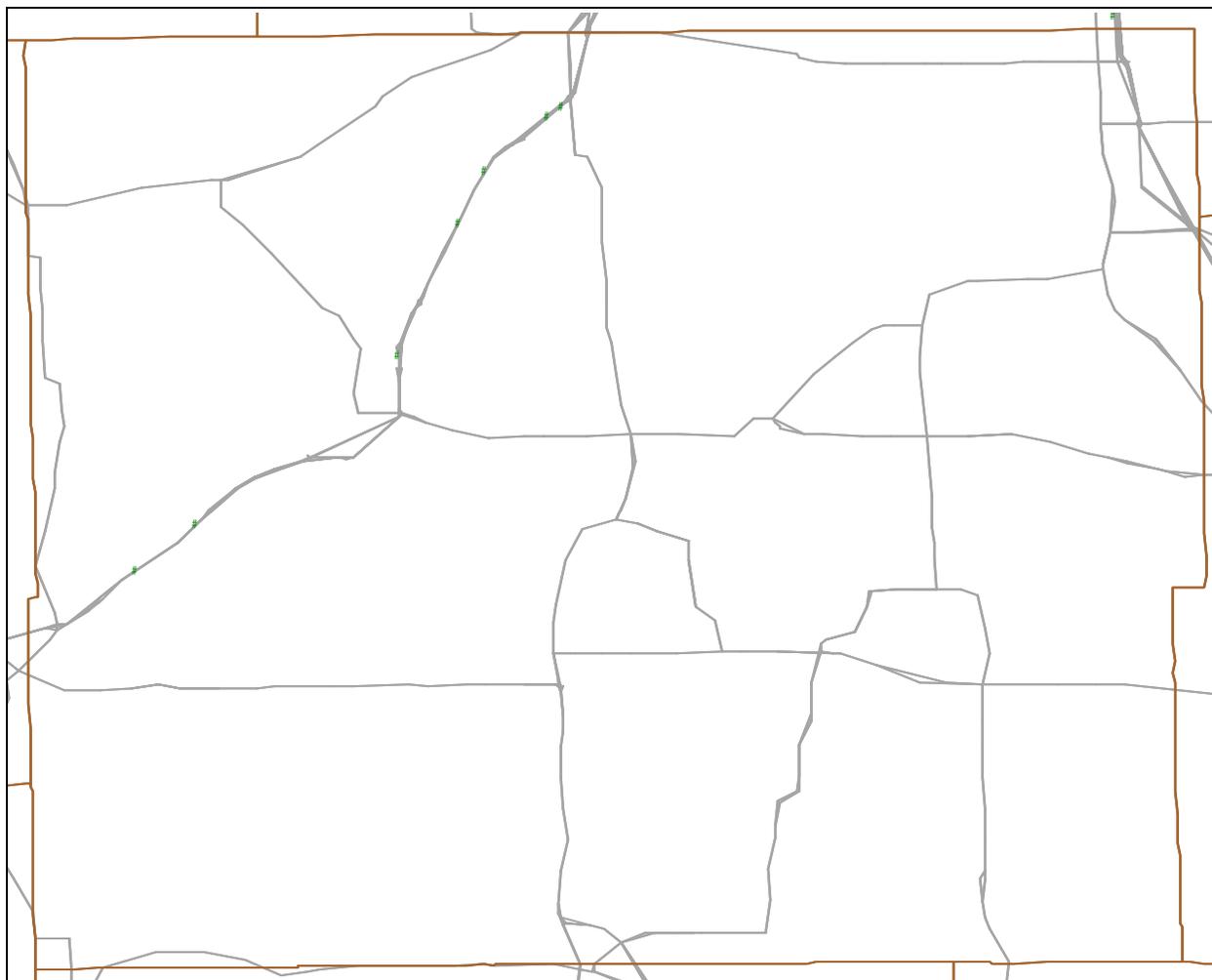


FIGURE A-12 2003 Dodge County Median Crossover Crashes.

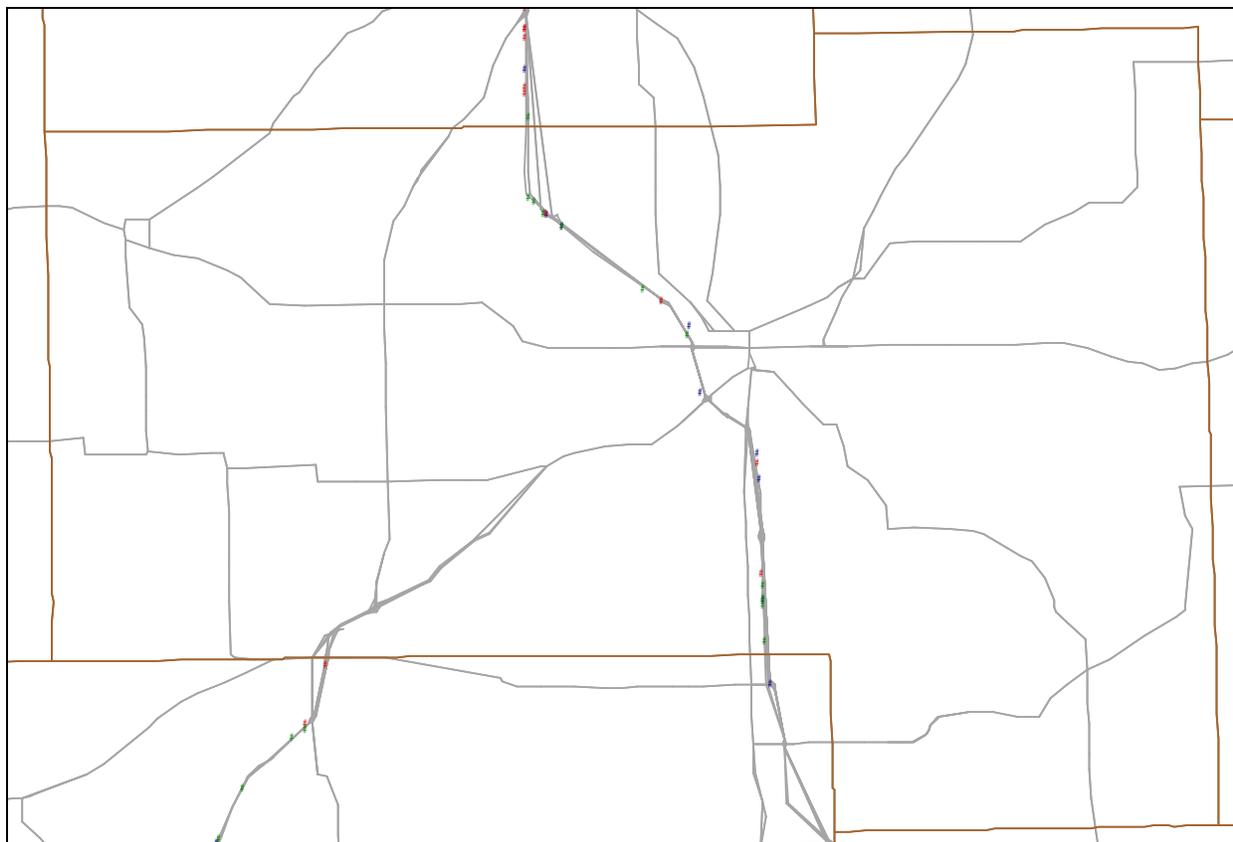


FIGURE A-13 Fond Du Lac County Median Crossover Crashes (2001 – 2003).

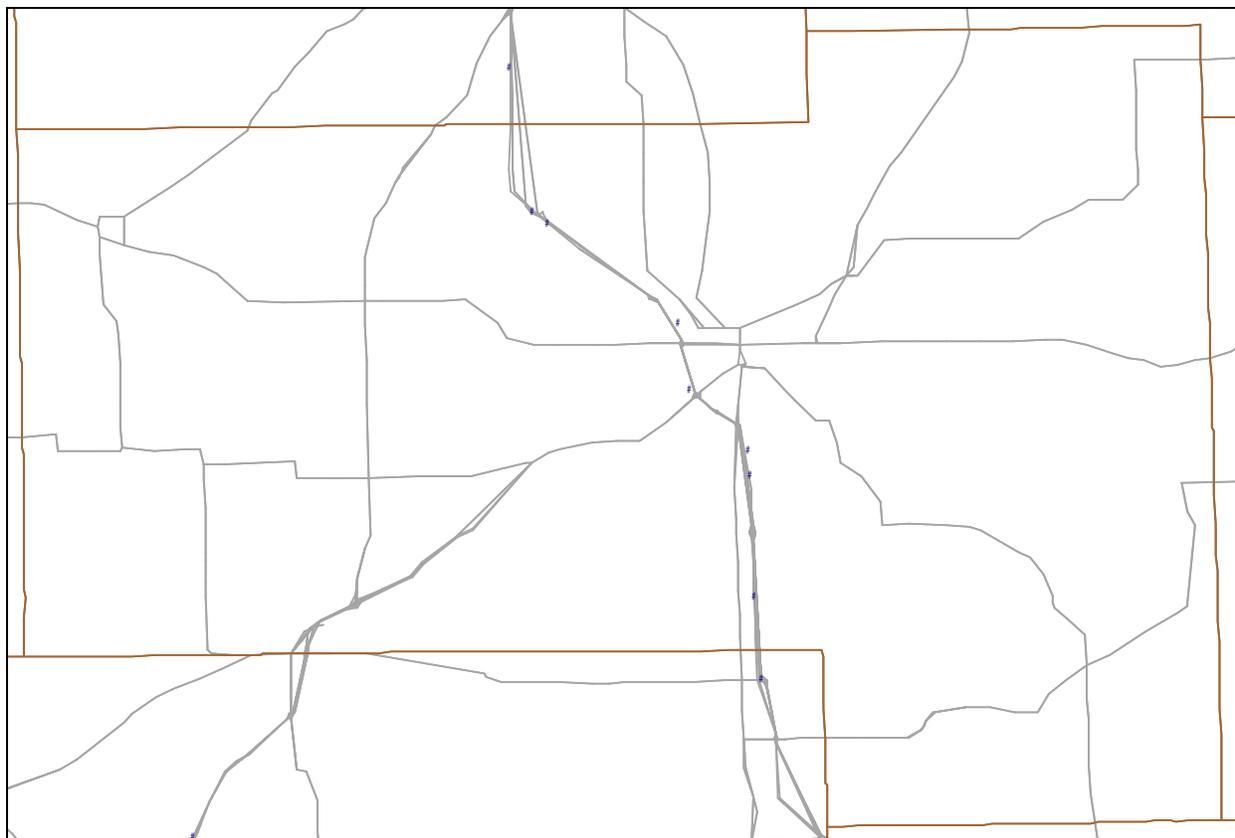


FIGURE A-14 2001 Fond Du Lac County Median Crossover Crashes.

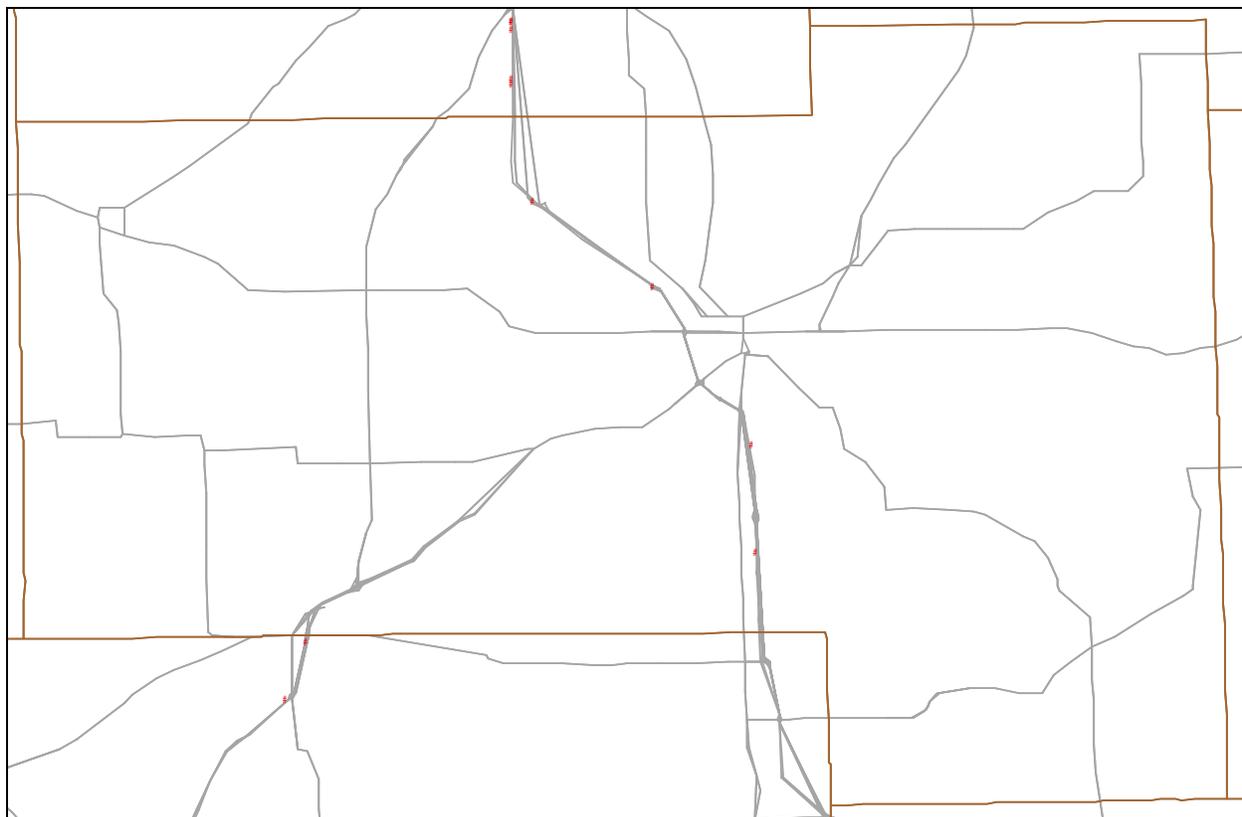


FIGURE A-15 2002 Fond Du Lac County Median Crossover Crashes.

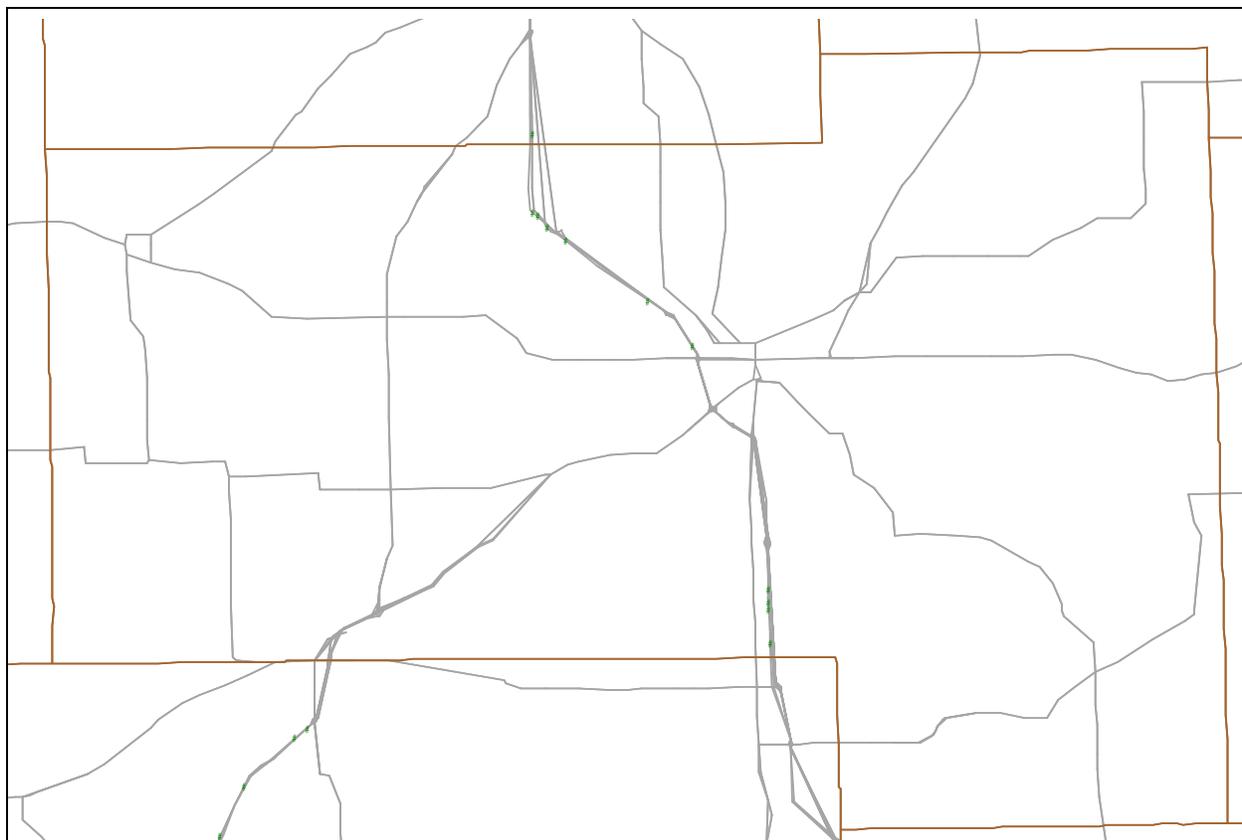


FIGURE A-16 2003 Fond Du Lac County Median Crossover Crashes.

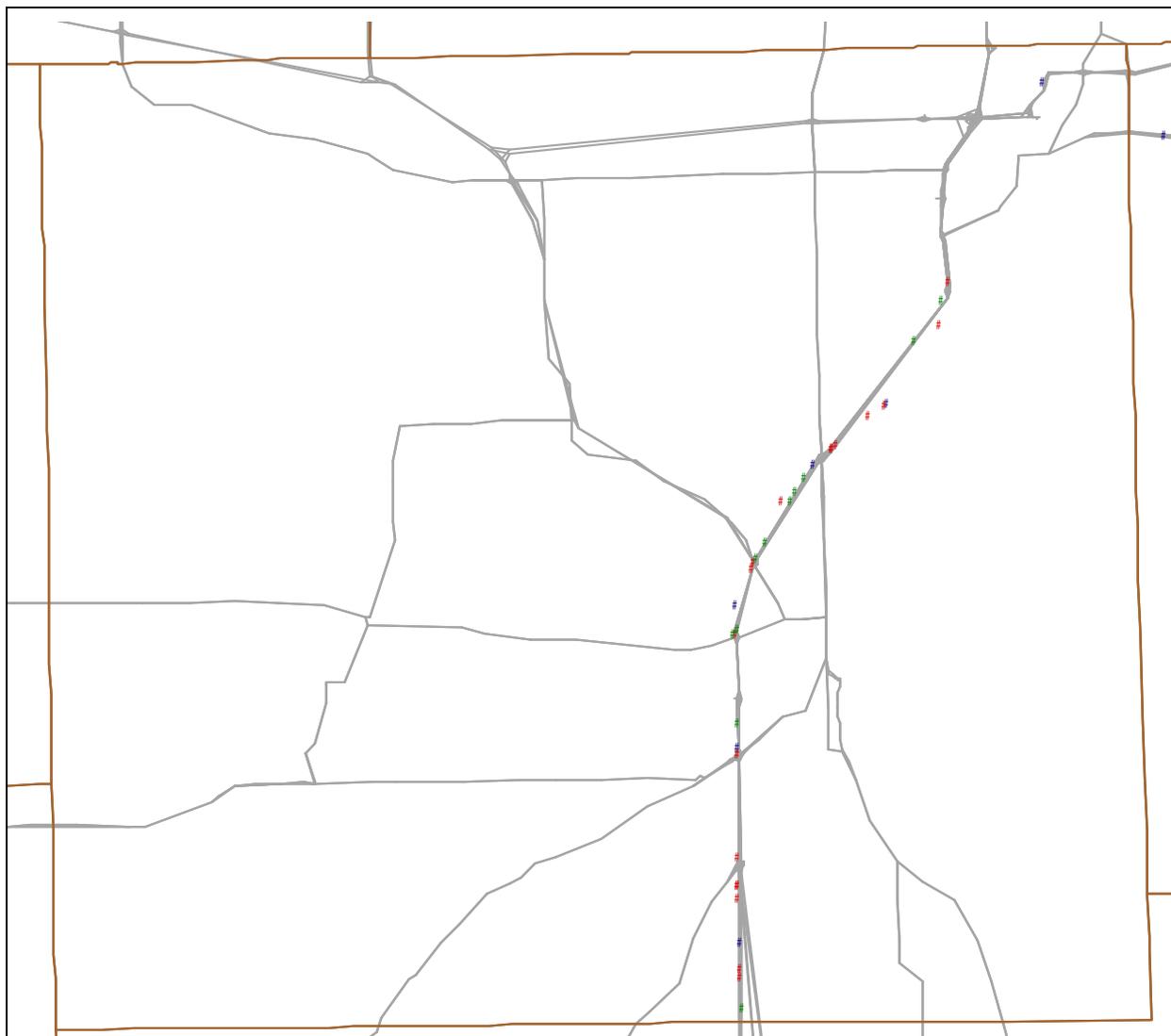


FIGURE A-17 Winnebago County Median Crossover Crashes (2001 – 2003).

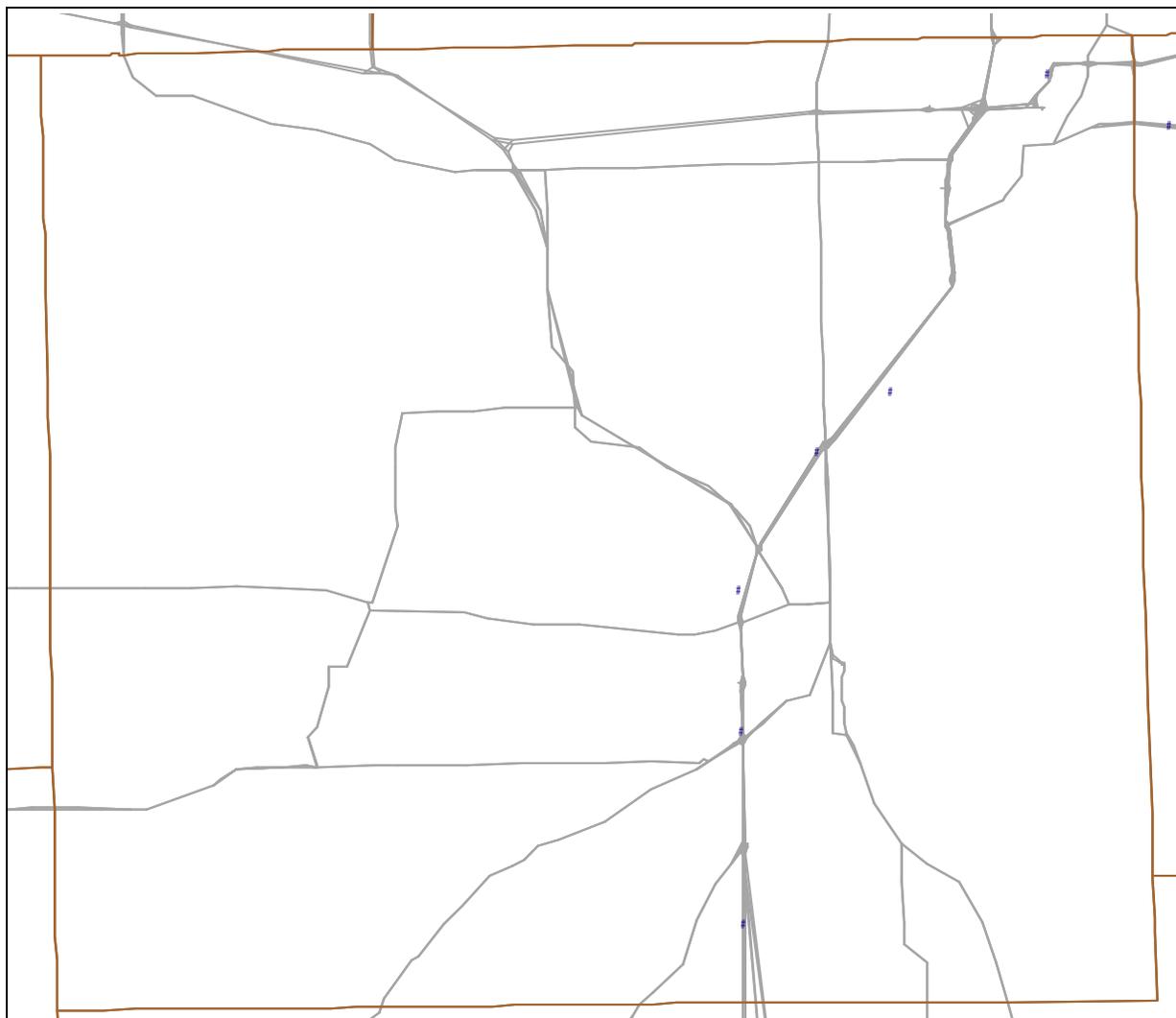


FIGURE A-18 2001 Winnebago County Median Crossover Crashes.

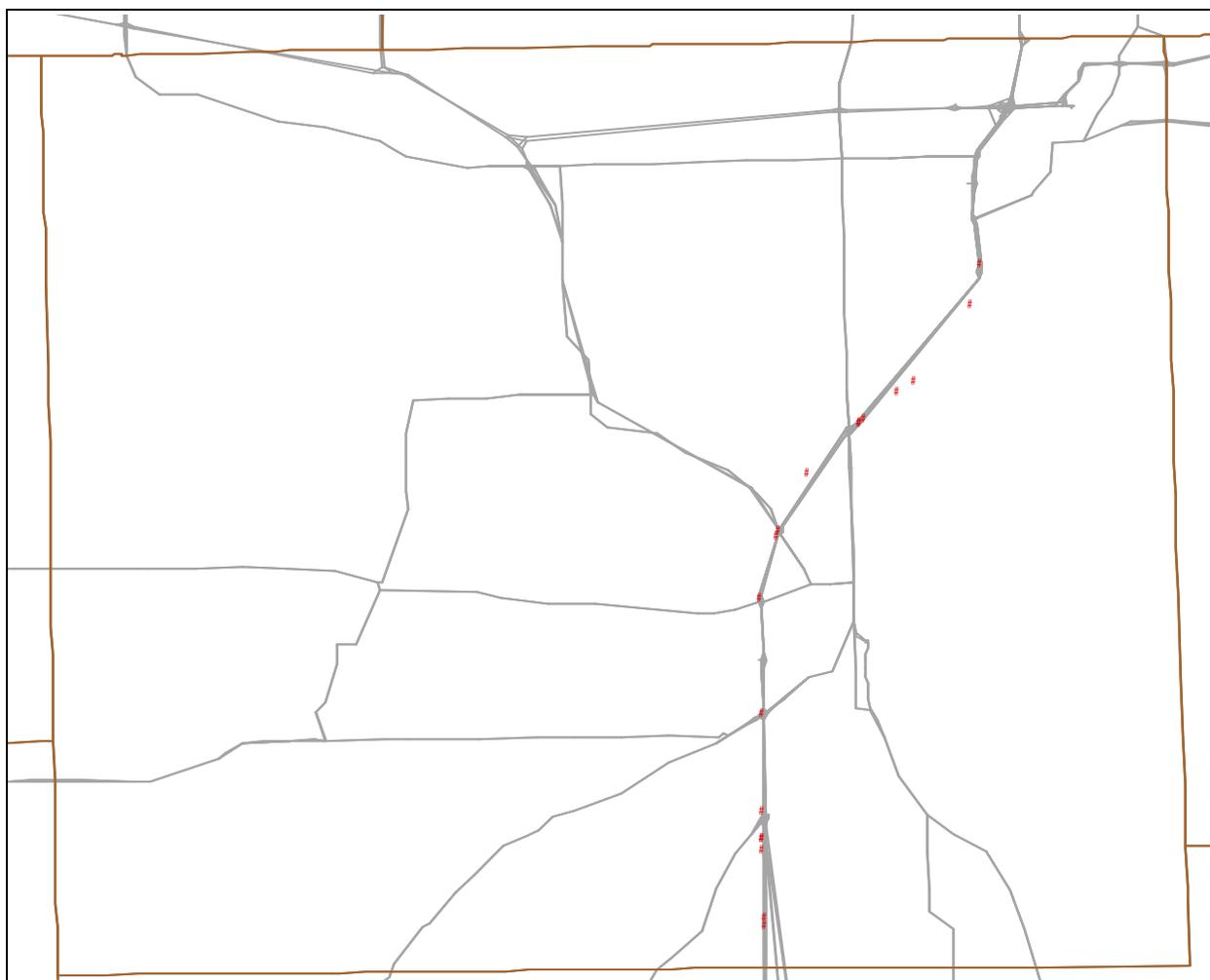


FIGURE A-19 2002 Winnebago County Median Crossover Crashes.

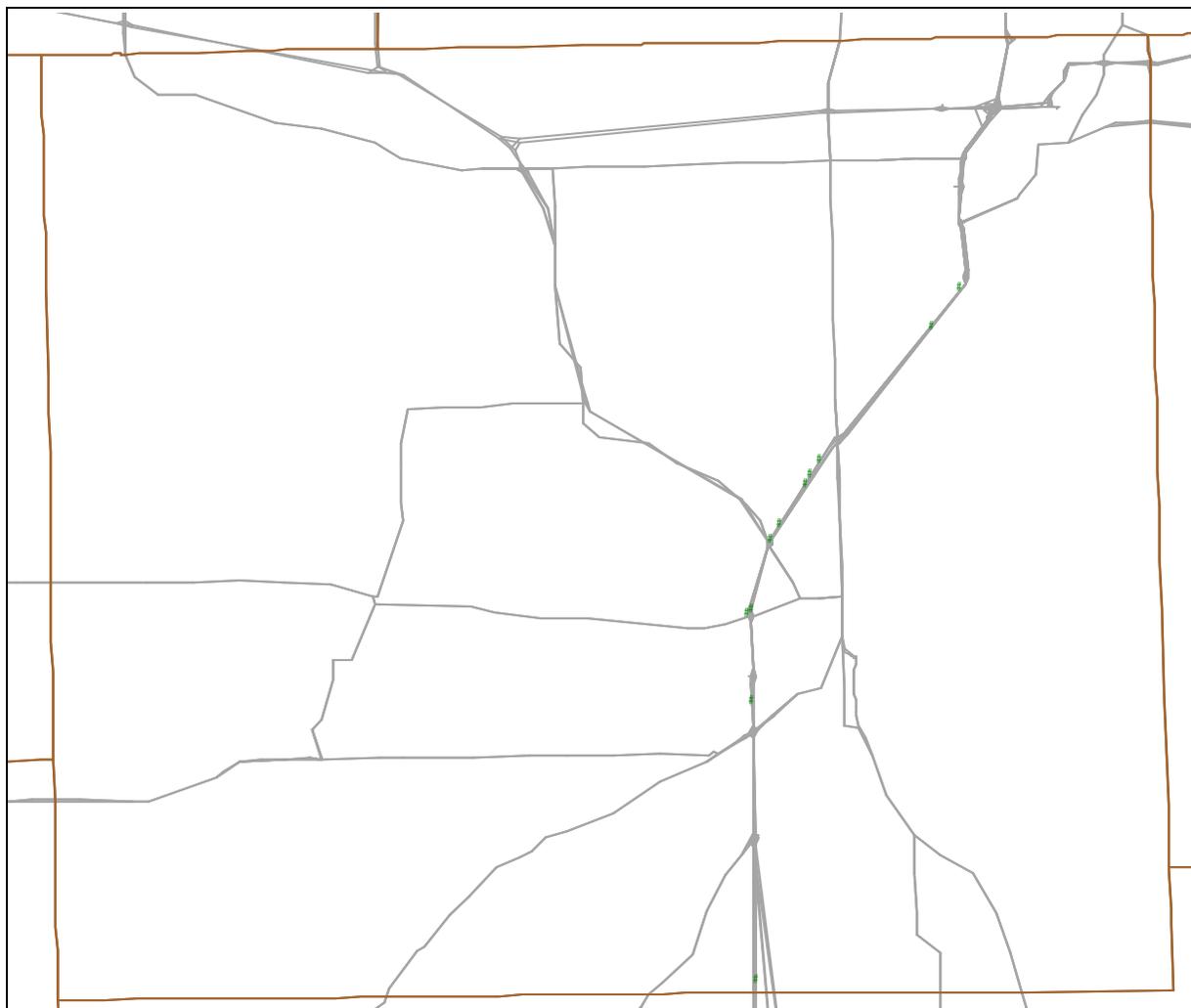


FIGURE A-20 2003 Winnebago County Median Crossover Crashes.

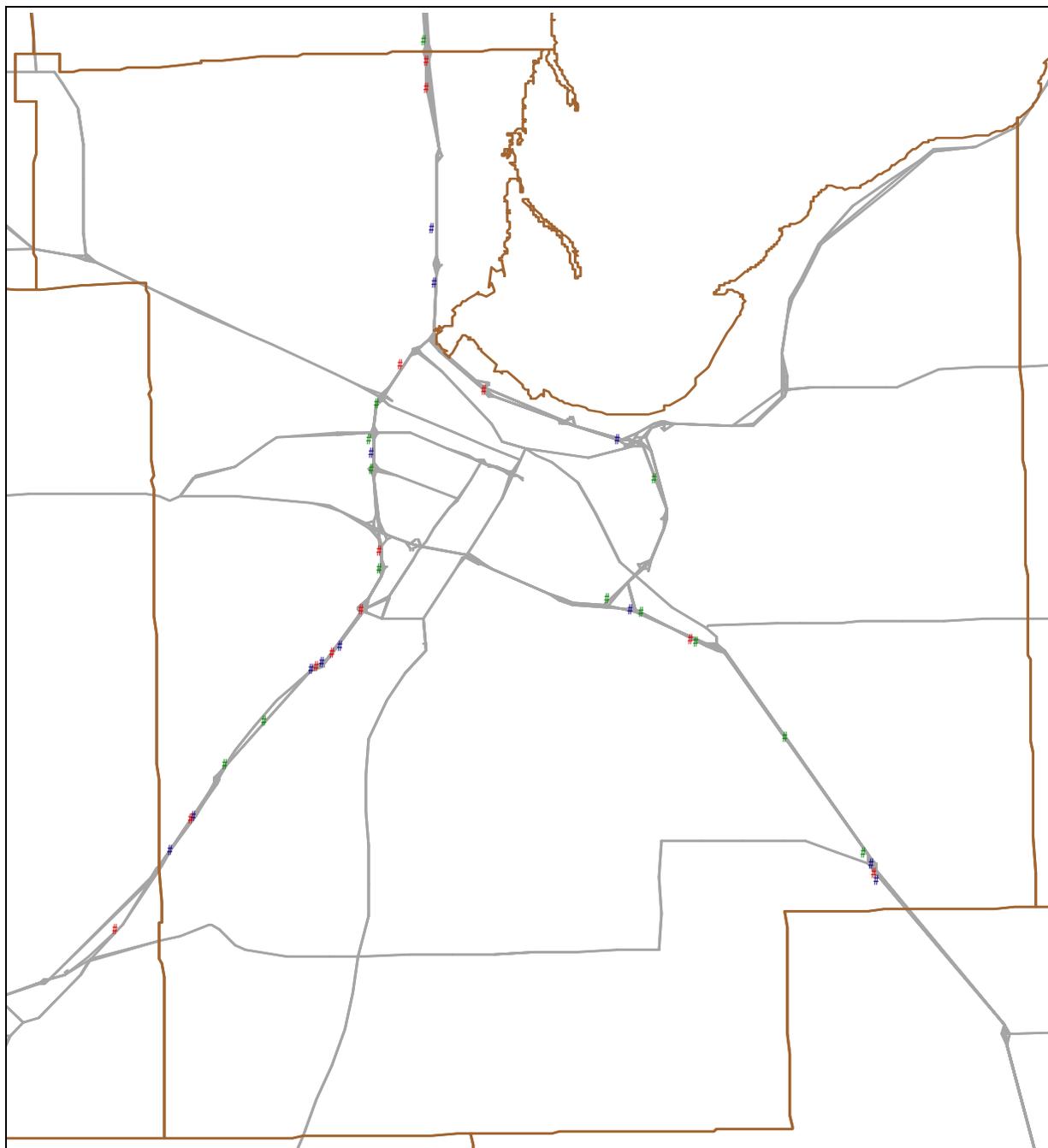


FIGURE A-21 Brown County Median Crossover Crashes (2001 – 2003).

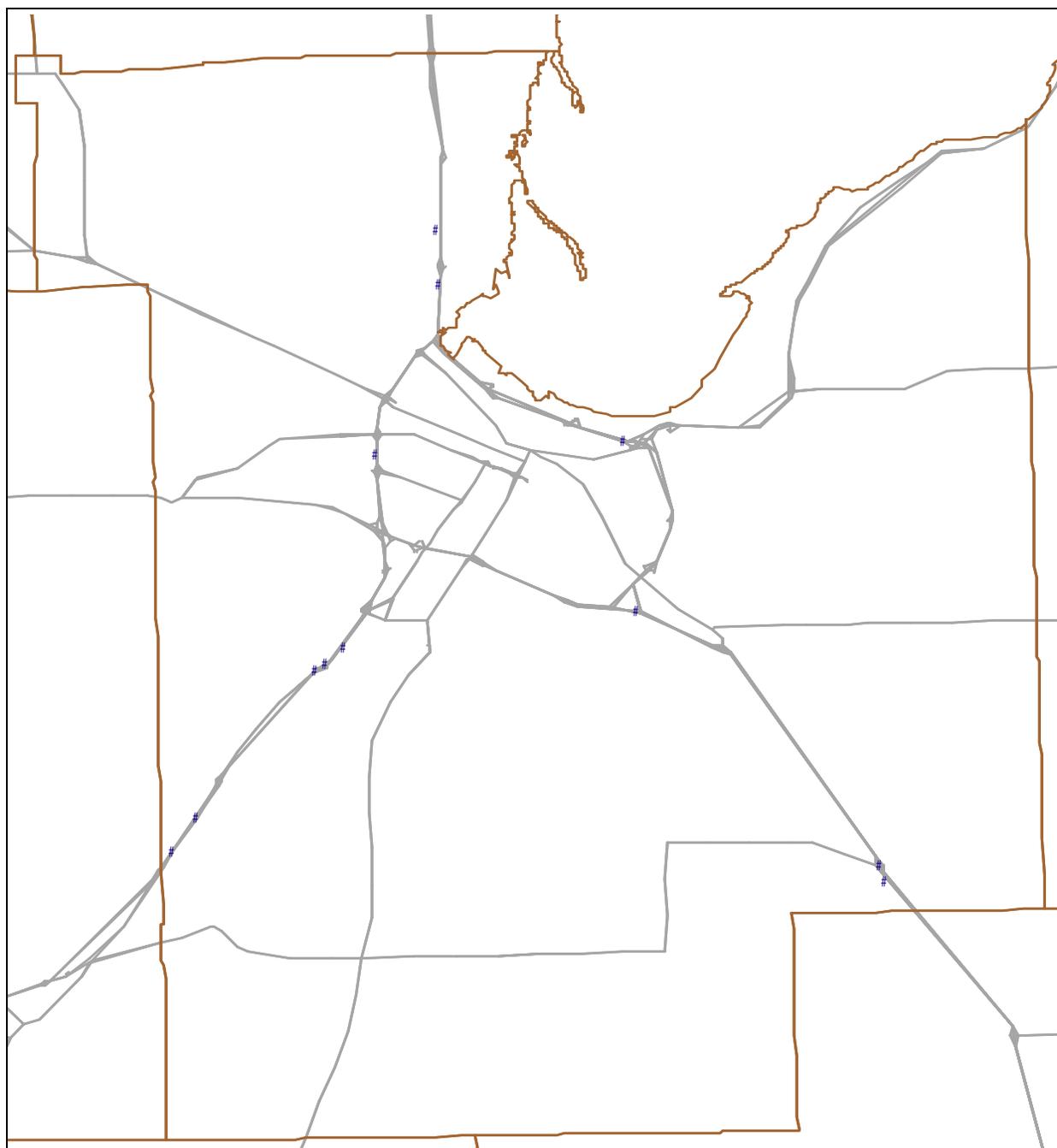


FIGURE A-22 2001 Brown County Median Crossover Crashes.

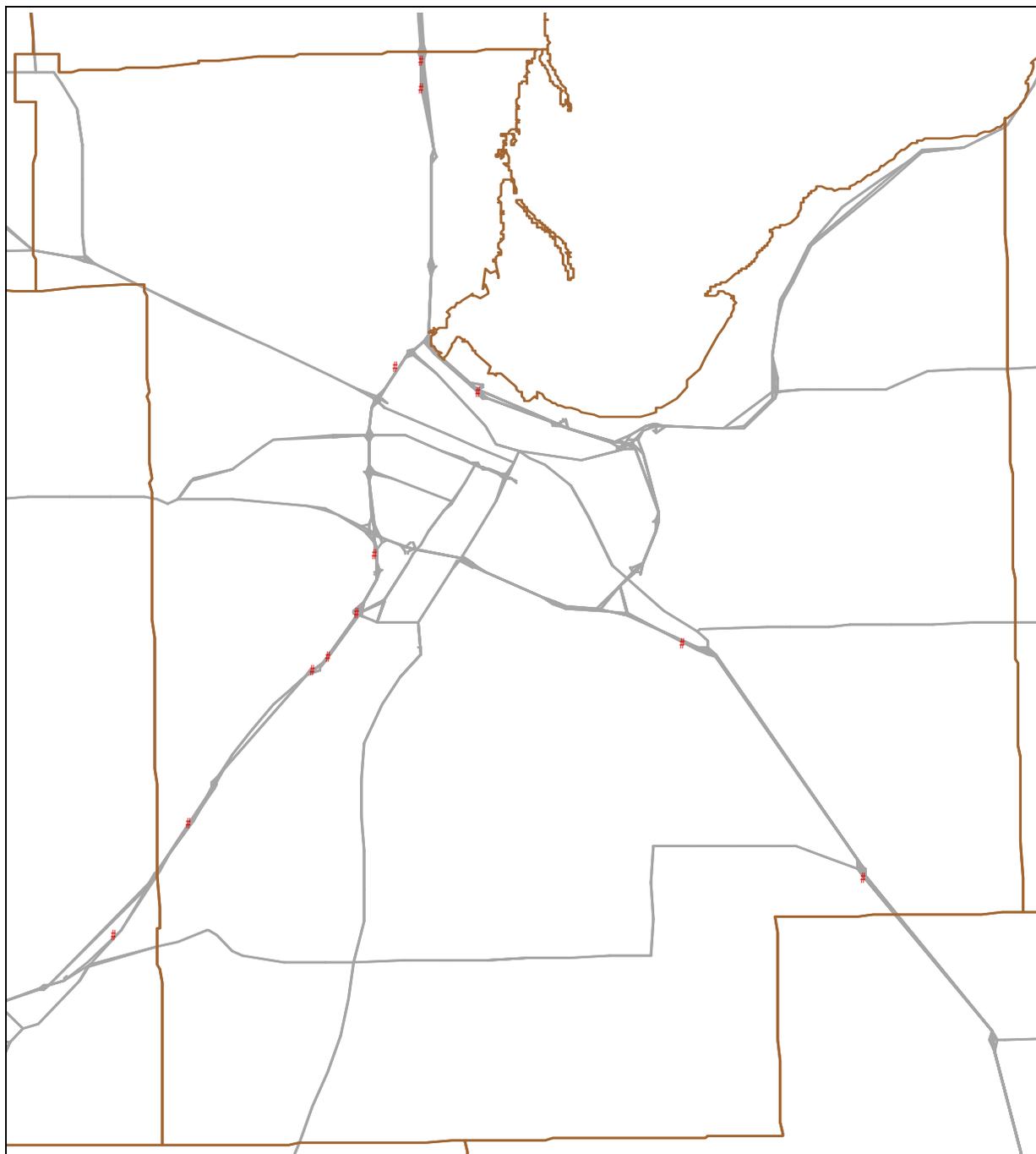


FIGURE A-23 2002 Brown County Median Crossover Crashes.

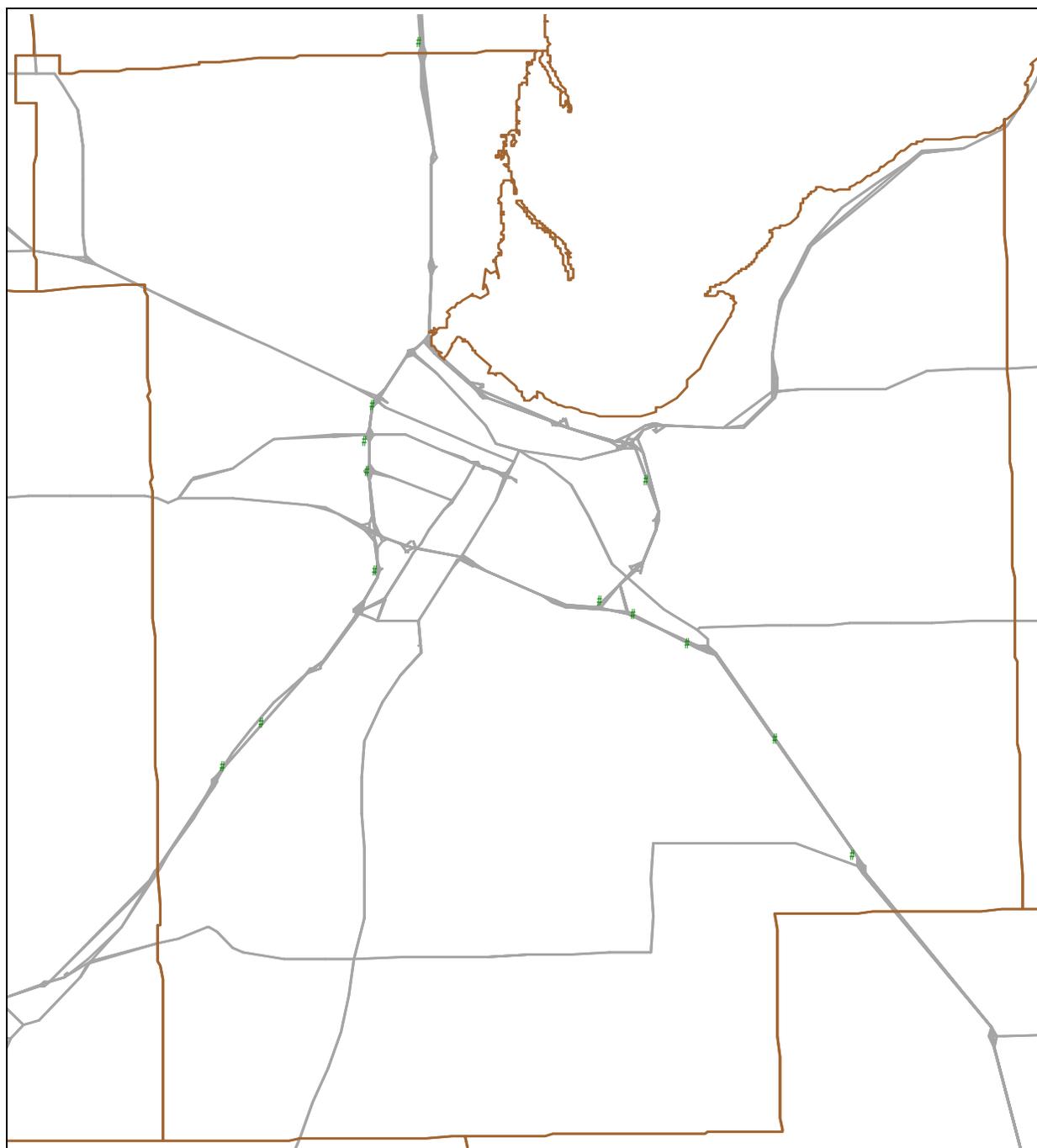


FIGURE A-24 2003 Brown County Median Crossover Crashes.

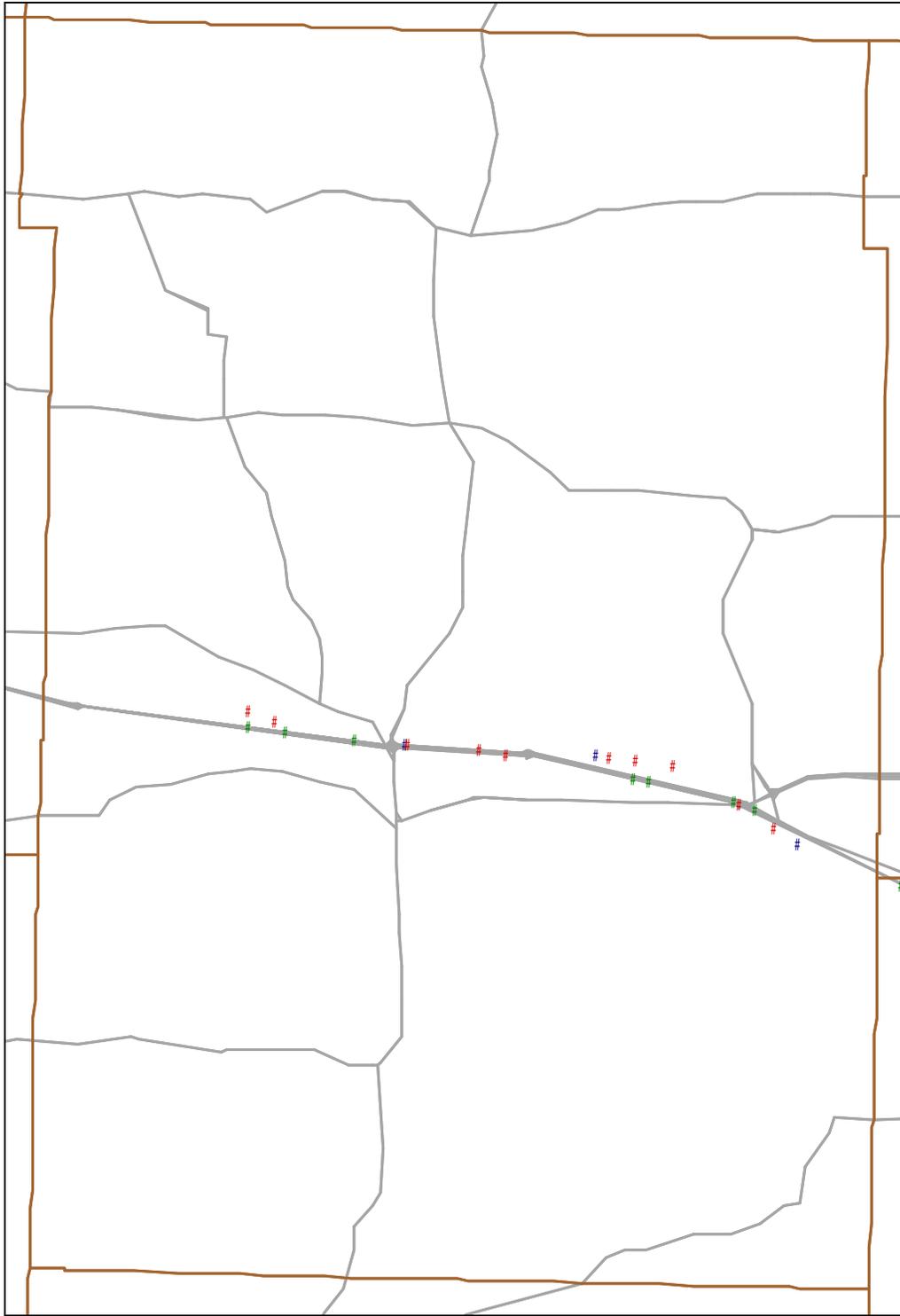


FIGURE A-25 Dunn County Median Crossover Crashes (2001 – 2003).

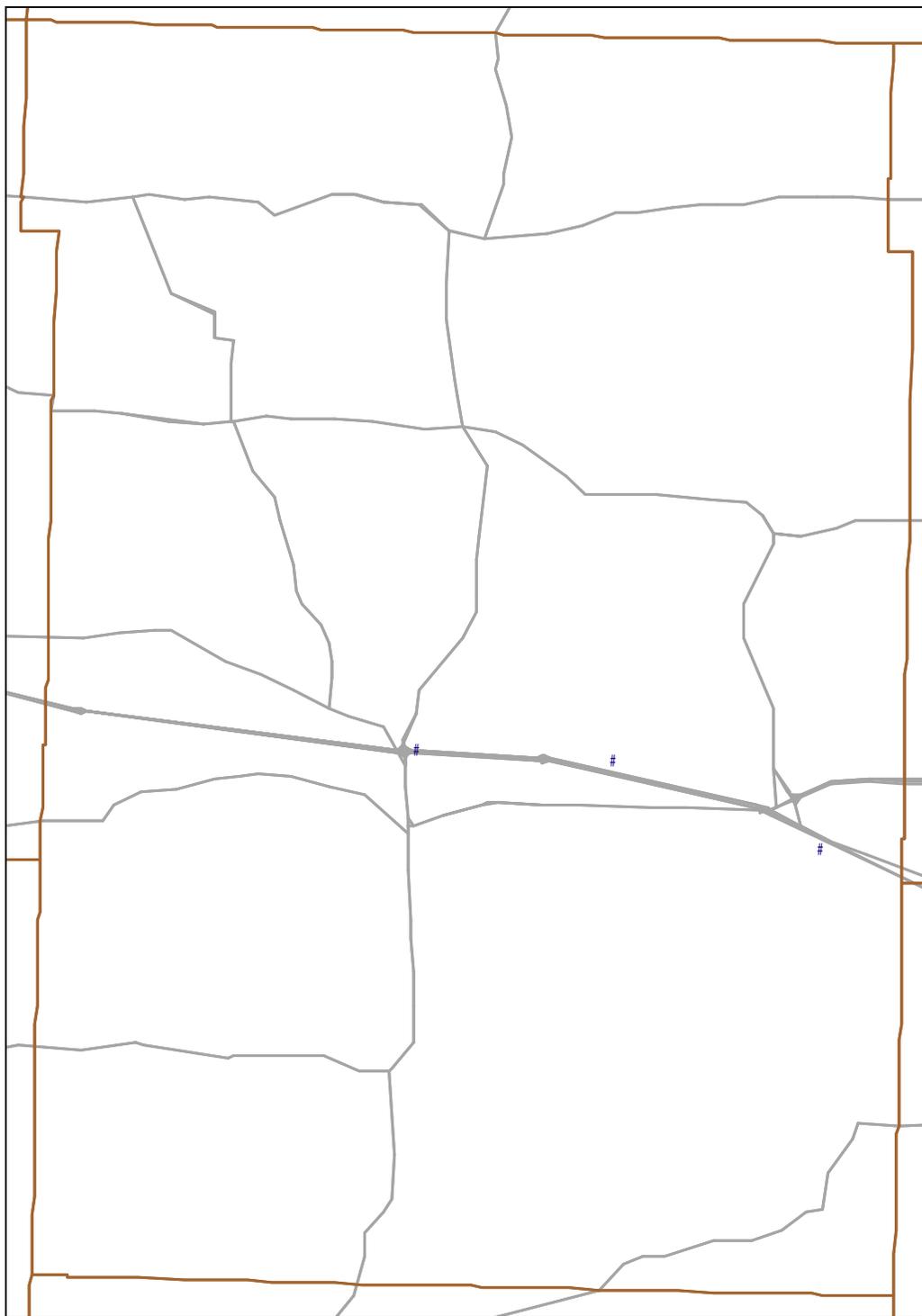


FIGURE A-26 2001 Dunn County Median Crossover Crashes.

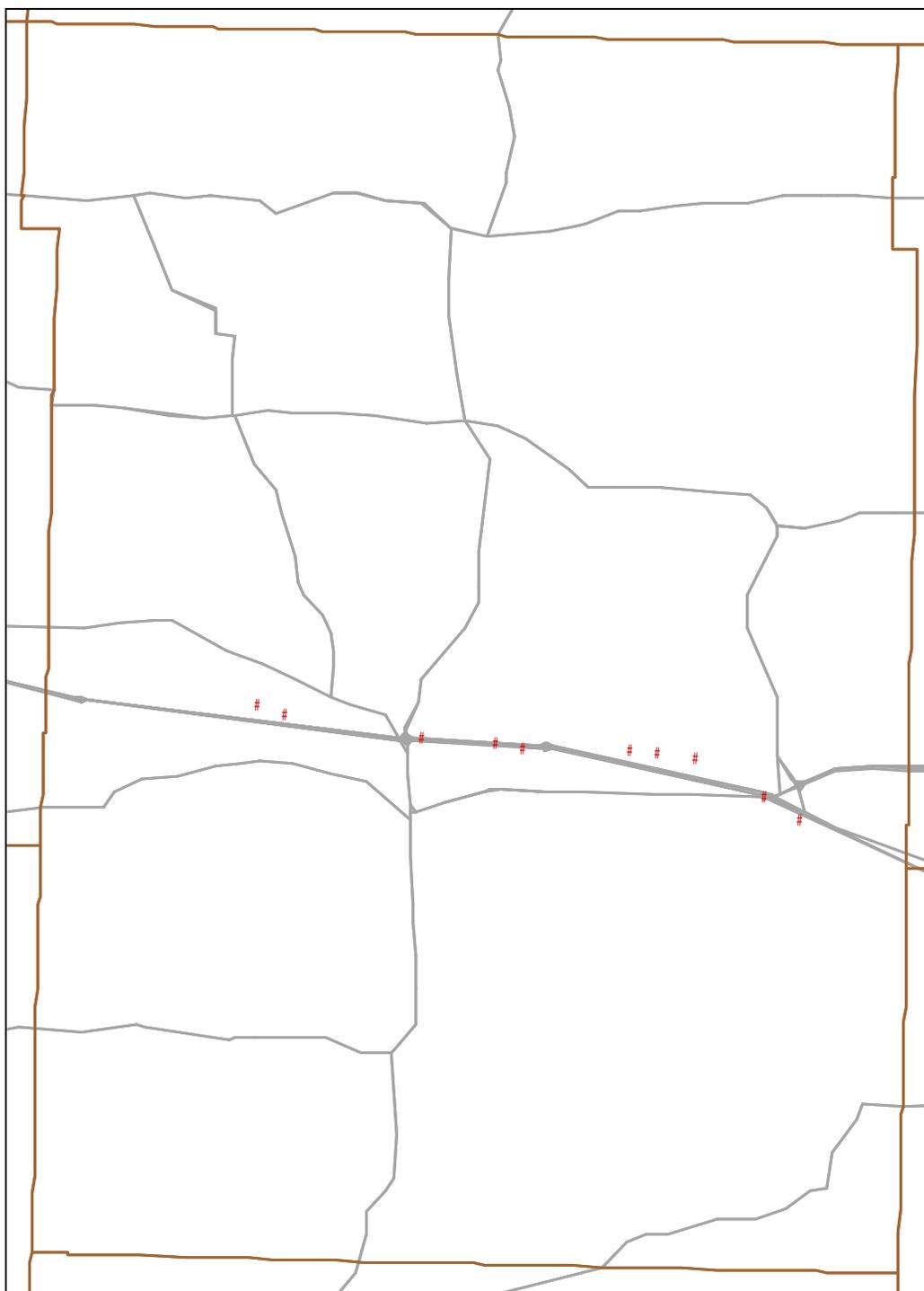


FIGURE A-27 2002 Dunn County Median Crossover Crashes.

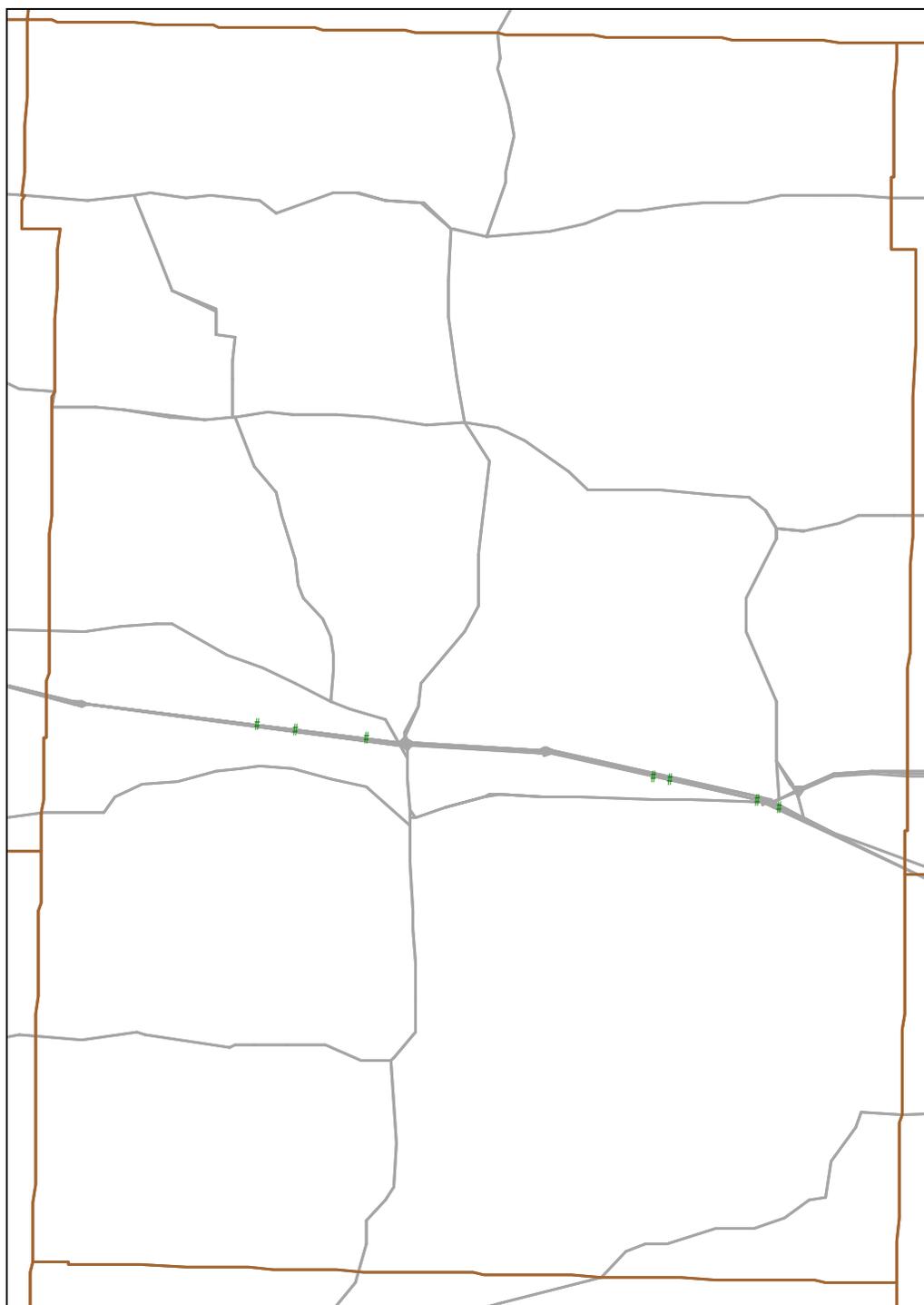


FIGURE A-28 2003 Dunn County Median Crossover Crashes.

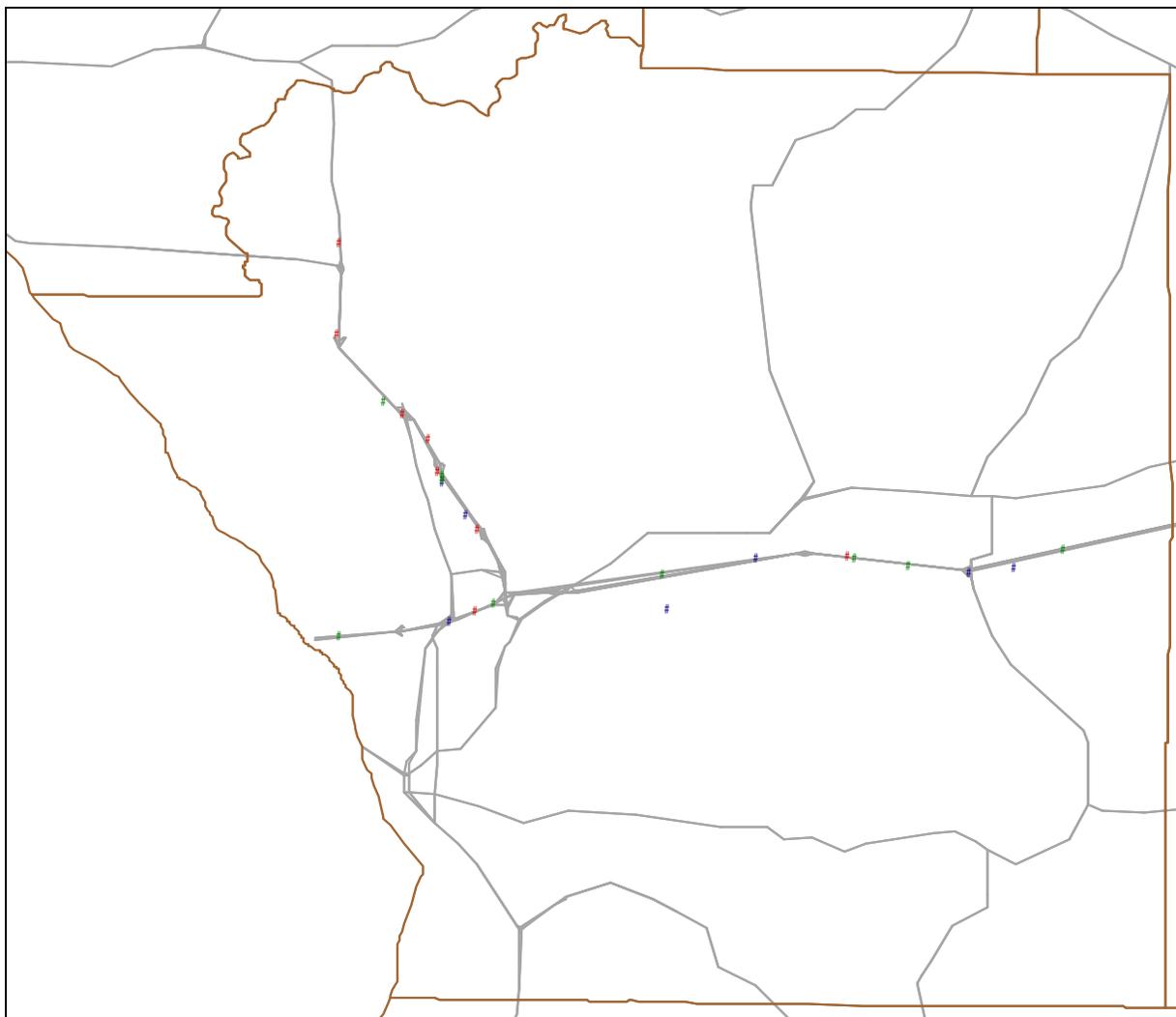


FIGURE A-29 La Crosse County Median Crossover Crashes (2001 – 2003).

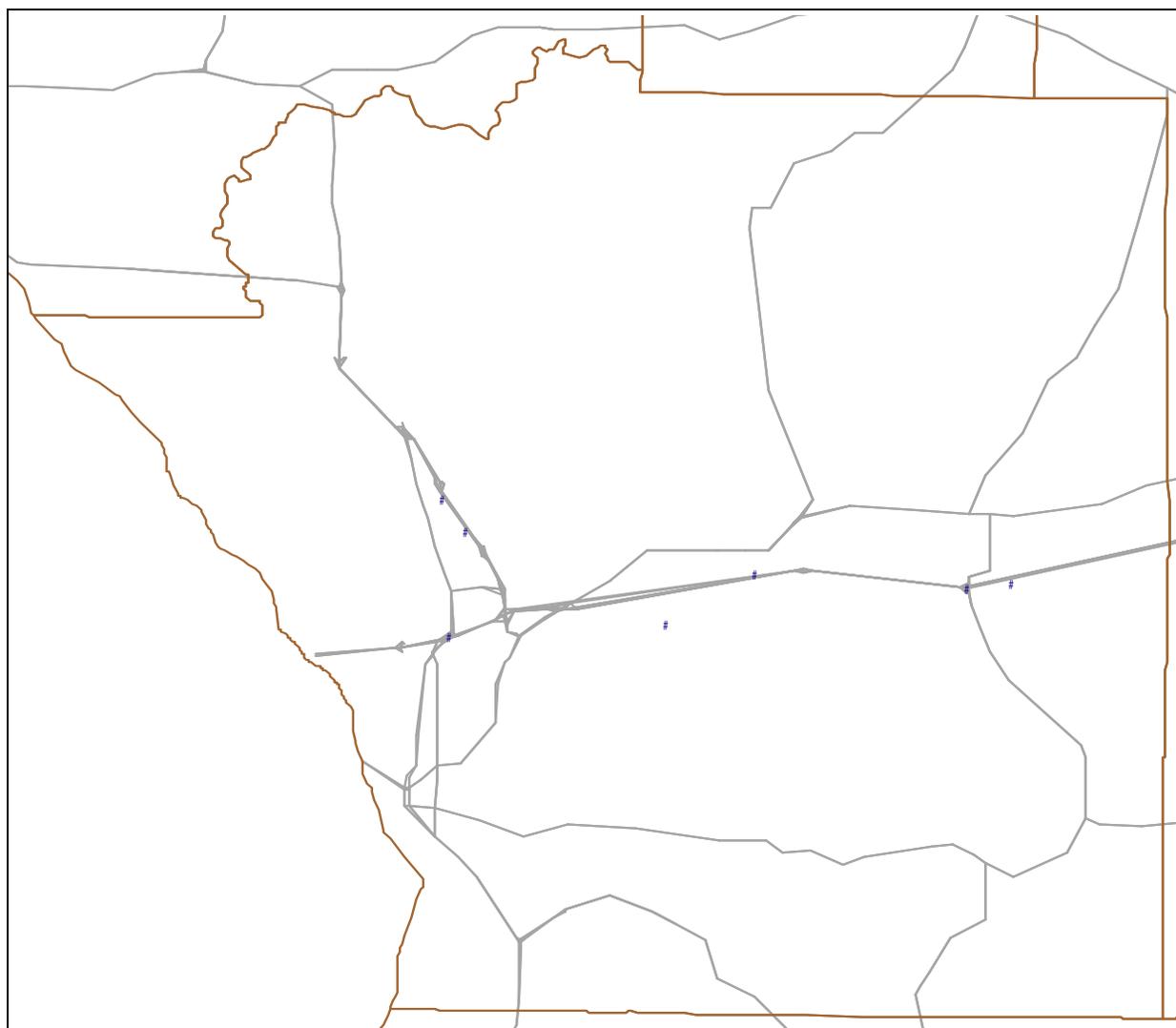


FIGURE A-30 2001 La Crosse County Median Crossover Crashes.

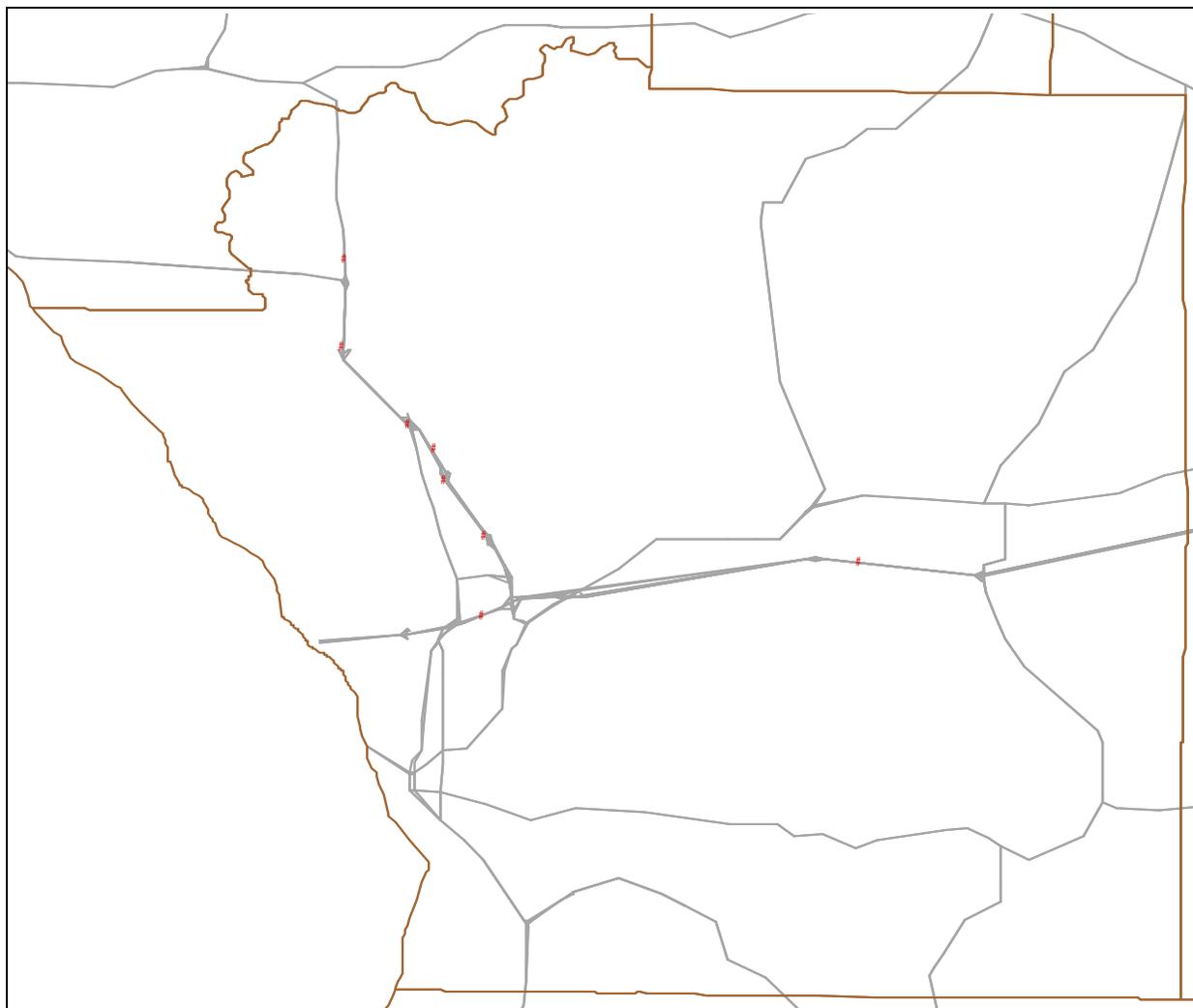


FIGURE A-31 2002 La Crosse County Median Crossover Crashes.

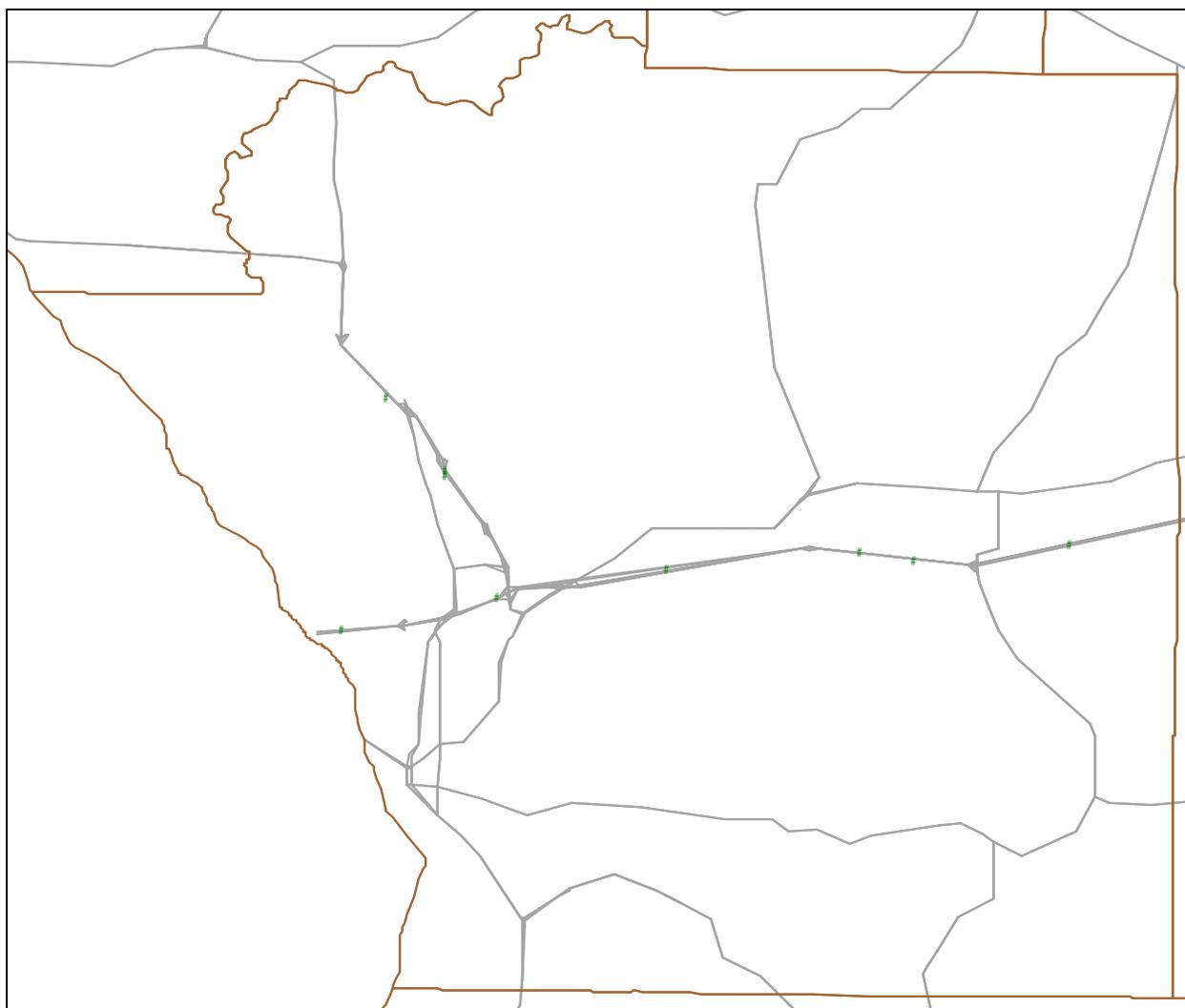


FIGURE A-32 2003 La Crosse County Median Crossover Crashes.