

Assessment of Collision Rates for Longitudinal Barriers

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INTRODUCTION

Roadside safety hardware became an integral part of highway construction during the 1960's and 1970's. Many guardrails and median barriers were designed, tested, and installed on the nation's roadways based on standards established during that time. As driver, vehicle, and traffic characteristics have changed and transportation professionals have gained improved understanding of vehicle and occupant behaviors during crashes with roadside safety hardware, that hardware has been upgraded. Accordingly, selection and placement guidelines have been modified. (1)

Because most highways are designed for a 20 to 30-year project life, many are now candidates for major rehabilitation which may include upgrading existing roadside safety hardware. Allocation of limited resources to achieve the greatest overall benefit for highway safety requires that transportation engineers have a comprehensive system-wide safety management system which incorporates roadside safety hardware and which uses some form of benefit/cost analysis.

Benefit/cost analyses consist of estimating the benefits to be derived from a course of action and comparing them with the costs of implementing that action. For roadside safety, the benefits are derived from expected reductions in future accident costs. To estimate these costs, expected numbers and severities of crashes are predicted using collision rates. In existing benefit/cost procedures, these rates are based on data collected in the 1960's and 1970's. (2)(3) In addition, these procedures focus on individual roadside safety installations, not on a system of installations.

A recently completed study on major highways in northern Connecticut provided detailed information for single-vehicle crashes with three types of longitudinal barriers; the cable guardrail or G1, the weak-post w-beam guardrail or G2, and the concrete safety shape. (4)

These crash data for northern I-91 were integrated with geometric and traffic data within a Geographic Information System (GIS) to calculate crash rates which could then be used within a comprehensive roadside safety management system. Because ROADSIDE is the currently accepted benefit/cost analysis procedure for roadside safety hardware, these crash rates were compared to collision rates predicted by that procedure.

Because data were available for all installations of three types of hardware on a 31-kilometer section of I-91, crash rates could be determined for a “system” of individual installations. How individual installation crash rates relate to a more system-wide crash rate is a previously unaddressed issue in roadside safety. Unlike the current Federal Highway Administration project to develop the Interactive Highway Safety Design Model (IHSDM), a suite of evaluation tools for assessing the safety impacts of geometric design decisions, (5) this approach begins to address management and rehabilitation of existing facilities.

DATA COLLECTION

Study Section

The study section used for this evaluation consists of approximately 31 km (19.5 mi) of northern Interstate 91 in Connecticut from the Massachusetts state line (milepost 58.00) to exit 35 (exit to I-84, milepost 38.45) in Hartford as shown in Figure 1. I-91 is a divided, controlled-access freeway with two to five 3.66 m-wide lanes in each direction, a design speed of 120 km/hr (75 mph), and posted speed limits of 105 km/hr (65 mph) in rural sections and 88 km/hr (55 mph) in urban sections. Three types of longitudinal roadside barriers exist on this section of the interstate; G1, G2, and concrete safety shape. Table 1 provides a summary of longitudinal barriers by type and general location. During the data collection period, total average daily traffic varied from 66,700 vpd at the northern state border to 138,800 vpd in downtown Hartford.

Crash Data

As part of the NCHRP study on In-Service Performance of Traffic Barriers, data were collected for crashes with longitudinal barriers on highways in northern Connecticut between July 1997 and June 1998. Bridge rails, crash cushions, transitions, and end treatments were not included in the data collection. As shown in Table 2, a total of 126 crashes were identified, 29 of which were unreported. Information about crashes was obtained from police reports, maintenance records, and visits to the site.

Although site visits were supposed to occur for all crash locations, locating the majority of police reported crashes was very difficult unless the barrier was repaired. Since this occurred for only five of the 99 police reported crashes, the remaining were not explicitly located. However, the remaining were geolocated according to milepost information provided by the police officer. Direction of travel and type of barrier were included in police reports for all crashes. Unfortunately, whether the crash occurred on the roadside or in the median was not included. By overlaying the geolocated crashes with the barrier inventory, as shown in Figure 2, crashes could be assigned to roadside or median, with the exception of two G2 crashes near Hartford that could have occurred on either side. Each crash could also be assigned to a specific installation using proximity, even though exact locations were not available.

As shown in Figure 3, a small number of G1 and G2 barrier sections within the study area were used as control sections to obtain information on unreported crashes. Within these control sections, identification of unreported crashes on the cable barrier was difficult because indication of minor damage was limited primarily to post movement which was difficult to discern. This probably indicates that unreported accidents on cable guardrails were under represented.

No attempt was made to obtain encroachment data since that was not the purpose of the project.

Geometric and Traffic Data

The geospatial center-line location of I-91, digitized at a reference scale of 1:100,000, was obtained from the Connecticut DOT. (6) Number of lanes and 1997 average daily traffic were also obtained from Connecticut DOT as text data with linear referencing according to ConnDOT's milepost system. (7) Figure 1 shows number of lanes while Figure 4 gives average daily traffic per lane. Longitudinal barrier locations were obtained directly from the 1996 videolog created and maintained by Connecticut DOT and were linearly referenced using the location stamp provided on the videolog and can be seen in Figure 3.

RESULTS

Collisions

One hundred twenty-six crashes were documented on the 86.98 kilometers of longitudinal barrier in the study section, of which, 99 were reported by the police. The number of police reported crashes may be conservative because Connecticut does not release accident reports until a case is closed and the possibility exists that all reports were not available prior to the end of the study period. However, information on all crashes that resulted in repairs to sections of G1 and G2 barriers were obtained.

Collision Frequency

Estimating number of collisions is a major part of any benefit-cost procedure for determining types and locations for roadside hardware and determining if upgrading of a barrier is cost effective. For design analyses, collision rates are typically determined from encroachment rates. An encroachment occurs whenever a vehicle leaves the traveled way and the collision rate refers to the number of times a barrier or hazard is actually struck by an encroaching vehicle. For this evaluation, collision rates were obtained directly from crash data, thus encroachments were not required.

Hardware installations in the study area were divided into north and southbound roadside and median components. System average crash rates were calculated for each type of hardware as the total number of crashes divided by the length of guardrail divided by the weighted average lane ADT. Next, average crash rates were calculated based on the crash rates for each individual installation. Since most police reported crashes could not be exactly located, they were instead identified with a specific barrier section. The crash rate was then calculated as the number of crashes per year for a particular barrier installation divided by the length of that installation, which was then divided by the appropriate single lane ADT along that section of barrier. Crash rates are shown in Figure 5 while ranges for crash rates are given in Table 3. Note that the lane ADT could and did vary along many of the installations. Obtaining segments with similar characteristics was performed within a GIS environment by defining I-91 as a “route” and dynamically segmenting number of lanes, ADT, and hardware location along the route.

System average crash rates were higher than average crash rates for G1 and G2 barriers because several individual installations did not have crashes during the one-year data collection period, thus lowering the average crash rates. The difference between the system and installation average crash rates was approximately 10% for G1 and 25% for G2. Part of this difference is due to the difference in total length of installations of each type of barrier as summarized in Table 1. For the concrete safety shape, the difference between system and installation average crash rates is 5% or less which probably reflects the fact that the length of safety shape installations is much longer than the other two barriers.

Observed crash rates for individual installations varied from a high of 0.00787 collisions/km/vehicles per day per lane (vpdpl) to a low of 1.939E-05 collisions/km/vpdpl. The two flexible barriers, G1 and G2, appeared to have comparable crash rates while the rigid safety shape had crash rates an order of magnitude lower. No comparison between types of barriers for median

versus roadside could be made because crashes for G1 and G2 occurred only on the roadside and crashes for the safety shape occurred only in the median. However, the difference in crash rates between the rigid barrier and two flexible barriers may be due to the distinction between roadside and median which reflects the fact that fewer reported crashes occurred in the median. Because of the limitations in locating crashes discussed earlier, no distinction could be made for horizontal curvature.

Unreported Crashes

During the NCHRP study to collect crash data, three G1 installations and four G2 installations, located in Figure 4, were investigated for unreported crashes. Table 4 compares police reported crashes with all identified crashes for these sections. Two sections had no police reported crashes and one unreported crash each while one section had no police reported and two unreported crashes. Of the remaining sections, two had an equal number of unreported and reported crashes, one had twice as many, and one had three unreported and two reported crashes.

For the combined G1 sections, only one in three accidents were reported while for G2 sections, three in five accidents were reported. As noted earlier, the unreported collisions with cable barriers could be much higher because of the difficulty in identifying evidence of drive-away impacts. Although these control sections are not directly representative of the total study section, the results can provide insight into reported versus unreported crashes for northern I-91.

From Fitzpatrick, et.al. on the results of vehicle collision frequency with concrete median barriers for an urban freeway in Connecticut, the police-reported crash rate for a section of concrete safety shape was one in four crashes. (9)

Collision Prediction Models

Several benefit/cost procedures have been developed for evaluation of roadside safety hardware. The most widely used procedure is the computer program, ROADSIDE (version 5.0), presented in the 1996 *AASHTO Roadside Design Guide*. (1) The collision prediction model is relatively straight forward, consisting of determining the number of collisions based on lateral extent of encroachment probabilities, a given encroachment rate, average daily traffic, design speed, and highway and roadside geometric characteristics. Because the probabilities are predefined in the program for a given combination of vehicles, angles, and speeds, the most complex input to the model is the distance from the traveled way to the point of impact adjusted for highway and roadside geometric characteristics. As the *Roadside Design Guide* indicates, given the many estimations and assumptions that these procedures include, the precision of the adjustment calculations greatly exceed the certainty of the procedure results. The procedures from the most recent version of the ROADSIDE program (Roadside 5.0) were used to estimate the collision rates (collisions/km/yr/vpdpl) and number of collisions for a single year for the study area.

A newly developed cost-effectiveness analysis program, the Roadside Safety Analysis Program (RSAP), was developed under NCHRP Project 22-9 and should soon be available for general distribution. (8) The encroachment frequency is calculated by determining a base or average encroachment frequency based on highway type and traffic volume and is then modified to account for specific highway characteristics such as vertical and horizontal alignment, number of lanes, and annual traffic growth factor. Probability of an accident given an encroachment is determined using the Monte Carlo simulation technique where a large number of encroachments are simulated and those causing crashes are identified. Because the simulation involved in RSAP was difficult to incorporate into the GIS framework at this time, only ROADSIDE was used for comparison with data collection results.

The same traffic and geometric data were used for the ROADSIDE calculations that were used to calculate actual crash rates. Horizontal degree of curvature was obtained from the geographic highway centerline database and varied from approximately 10° to straight segments. Vertical curvature, cross-sectional slope, and superelevation for the entire study section were unavailable at the time of this study. Distance from the edge of traveled way to the barrier face was also not available for each barrier. Instead, Connecticut DOT's recommended design values were used for each barrier type. Vehicle mix on the highway was taken as the default from ROADSIDE.

As can be observed from Table 5, ROADSIDE generally over predicted number of collisions if only police-reported crashes are considered and generally under predicted number of collisions if unreported crashes are included. Predicted collisions compared favorably for police-reported crashes with the G1 cable barriers, while the predicted collisions for both the G2 w-beam rail and the concrete safety shape compared better when unreported crashes were included. Previously reported results from the NCHRP study indicate that approximately 75 percent of crashes with concrete median barriers in heavily traveled urban areas are unreported. (9) Adjusting for this gives very close values for northbound crashes and higher numbers for southbound crashes, approximately 80 actual vs 73 predicted and 112 actual vs 75 predicted, respectively.

The variability between maximum and minimum crash rates, (excluding sections with no crashes), was somewhat greater for actual crash data. The predicted weighted-average collision rates were a third to nearly three times higher than the actual weighted-average crash rates.

DISCUSSION

The purpose of this work was two-fold. First was to evaluate available crash data to determine crash rates for three types of longitudinal barriers. These rates would then be available for use in benefit-cost analyses to evaluate upgrading, or possibly removing, existing systems. Second was to explore a broader evaluation of crash rates related to roadside safety. Typically, benefit cost analyses are performed on a project by project basis which generally cover individual installations. With the availability of GIS and system-wide georeferenced inventory and traffic information, a more global approach appears to be warranted. Although this work currently focuses only on crash rates, insight can be obtained about what limitations exist and issues that should be considered when looking at a larger study region.

Collisions

The primary source of crash data was from police reports implying that the majority of unreported crashes were not accounted for. Although the data collection effort included regular investigations of selected installations to help identify this population, collection was not feasible for the entire study area. For evaluating upgrades to or rehabilitation of existing hardware, unreported crashes may not be necessary. Except for routine repairs or unusual damage, barriers are not repaired for “routine” bumps, scratches, and dings which typically result from unreported crashes. Therefore, costs directly associated with unreported crashes are not incurred and benefits can be determined from differences between police-reported crash rates and severities for different types of hardware.

For regional system-wide analyses, police reports will probably be the source of crash rates because this information is readily available and recent efforts have increased the likelihood that it will be georeferenced. The critical issue for whether it can be used is if roadside safety hardware is adequately classified in the report. The current practice of identifying crash location

by milepost or landmark limits the ability to accurately associate highway characteristics with the crash site. One hundred meters, the accuracy of many spatial highway data bases as well as uncorrected global positioning coordinates, can mean the difference between barrier types, curvature, or intersecting roads. If differential global positioning systems (DGPS) are used to locate crashes, this will not be an issue, although the geographic representation of the underlying highway may then become a problem.

Collision Frequency

Because crashes are random extreme events, models to predict when and where they occur are only indicators at best. ROADSIDE provided a crash rate for every section of barrier that was included. In reality, only 63 of the 147 separate installations were struck, meaning that 84 segments had a crash rate of zero. This is the primary reason why the actual weighted average crash rates were lower than predicted rates. That a zero crash rate should not be used for analysis purposes is clear since the probability that a vehicle will impact a barrier is not zero. What is unclear is whether the zero crash rates should be included in a weighted average or whether some other method for defining crash rates for a regional area with multiple installations should be developed.

As shown by the data in Table 4, the crash rate predictions based on ROADSIDE were different from observed values. One possible explanation is that even the rural portion of I-91 is heavily traveled. Much lower volume roadways dominated the Hutchinson-Kennedy study, which forms the basis of the encroachment model in ROADSIDE. Also, within the analysis procedure, the volume of traffic is not clearly accounted for in multi-lane highways. Even if specific lane volumes were available, and not the total ADT divided by number of lanes, some crashes occur when vehicles cross multiple lanes to impact the object on the roadside.

CONCLUSIONS

Several factors have been identified during this effort. First, crash rates could be determined from police reported crashes for individual installations and for the system. Further work needs to be done for system-wide analyses to determine how to incorporate zero crash rates into an appropriate collision rate or rates.

Collisions predicted by ROADSIDE varied from reported crashes by as little as 11% and as much as 75%, under predicting crashes with safety shapes and over predicting crashes with G1 and G2 barriers. When number of crashes was adjusted for unreported crashes using factors from this work, predicted collisions varied from crashes by 7% to 70%, but now over predicting crashes with safety shapes and under predicting crashes with G1 and G2 barriers. Variation between predicted collision rates and calculated crash rates are due in part to lack of detailed offset information and the fact that the characteristics of this study segment were much different from the data sets used to develop the encroach models for ROADSIDE. The reverse in over and under predictions that occurs when unreported crashes are included may be related to differences in traffic volume by lane which exist for roadside versus median lanes on freeways. The nature of vehicle collision rates on high-volume high-speed freeways in both rural and urban areas is still not well understood.

GIS is an effective tool for bringing multiple sets of highway, traffic, and crash data together to calculate crash rates leading to benefit cost analyses and safety management. Spatial referencing of data continues to be a very real issue. Of the different data sets used in this project, four spacial references were included: latitude/longitude, state route mileposting, linear referencing from the GPS associated with the video log, and police estimated mile points, none of which were concurrent. With accurate geo-referencing, this type of study could provide the ability to predict crash rates based on crash, inventory, and traffic information.

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REFERENCES

1. Task Force for Roadside Safety. *Roadside Design Guide*, American Association of State Highway and Transportation Officials, Washington, D.C., January 1996.
2. Hutchinson, J. W. and T. W. Kennedy. Medians of Divided Highways -- Frequency and Nature of Vehicle Encroachments. *Engineering Experiment Station Bulletin 487*, University of Illinois, 1966.
3. Cooper, P. J. Analysis of Roadside Encroachment Data Analysis from Five Provinces and its Application to an Off-Road Vehicle Trajectory Model. British Columbia Research Council, Vancouver, Canada, 1981.
4. Ray, M. H., W. W. Hunter, D. L. Harkey, and K. L. Hancock. "In-Service Performance of Traffic Barriers: Data Collection Procedures," National Cooperative Highway Research Program Project 22-13, The University of Iowa, Iowa City, IA, 1998.
5. Krammes, R. A. IHSDM Overview. Office of Safety Research & Development, Federal Highway Administration, <http://www.tfhr.gov/safety/ihsdm/brief.htm>, accessed July 29, 1999.
6. Connecticut Department of Transportation, Bureau of Policy and Planning. *1995 ConnDOT Cartographic/Transportation Data* (CD-ROM), Issued March 1997.
7. Connecticut Department of Transportation, Bureau of Policy & Planning, Documents. <http://www.state.ct.us/dot/bureau/pp/pp.html>. Accessed May 1, 1999.
8. Mak, K. K. *Roadside Safety Analysis Program -- User's Manual*. National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., 1997.
9. Fitzpatrick, M. S., K.L. Hancock, and M. H. Ray. "Videolog Assessment of the Vehicle Collision Frequency with Concrete Median Barriers on an Urban Highway in Connecticut", accepted for publication by the Transportation Research Board, National Research Council, Washington, D.C., 1999.

TABLE 1 Length of Longitudinal Barrier by Type and Direction

Type	Northbound I-91				Southbound I-91			
	Roadside		Median		Roadside		Median	
	Length (km)	Number of Installations	Length (km)	Number of Installations	Length (km)	Number of Installations	Length (km)	Number of Installations
G1	1.98	10	0.00	0	1.61	8	0.00	0
G2	12.54	47	0.41	3	11.72	53	0.61	3
CMB	0.74	7	28.54	7	0.40	1	28.43	8

TABLE 2 Summary of Longitudinal Barrier Crashes

Northbound I-91							
Type	Roadside			Median			TOTAL
	Police Reported	Unreported	Total	Police Reported	Unreported	Total	
G1	4	6	10	0	0	0	10
G2	23	13	36	0	0	0	36
CMB	0	0	0	20	0	20	20
Total	27	19	46	20	0	20	66

Southbound I-91							
Type	Roadside			Median			TOTAL
	Police Reported	Unreported	Total	Police Reported	Unreported	Total	
G1	4	2	6	0	0	0	6
G2	18	8	26	0	0	0	26
CMB	0	0	0	28	0	28	28
Total	22	10	32	30	0	30	60
TOTAL ALL ACCIDENTS							126

TABLE 3 Summary of Longitudinal Barrier Crash Rates (collisions/km/vpdpl) (a)

Northbound I-91							
Type	Roadside				Median		
	System Average (b)	Average (c)	High	Low (d)	System Average (b)	Average (c)	High
G1	1.414E-04	1.271E-04	7.808E-04	1.233E-04	-	-	-
G2	1.284E-04	9.191E-05	6.342E-04	2.582E-05	0.000E+00	0.000E+00	0.000E+00
Safety Shape	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.904E-05	5.157E-05	8.643E-05

Southbound I-91							
Type	Roadside				Median		
	System Average (b)	Average (c)	High	Low (d)	System Average (b)	Average (c)	High
G1	1.739E-04	1.548E-04	6.246E-04	1.776E-04	-	-	-
G2	1.075E-04	8.437E-05	7.808E-04	4.757E-05	0.000E+00	0.000E+00	0.000E+00
Safety Shape	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.892E-05	6.977E-05	1.758E-04

(a) Collisions per kilometer per vehicles per day per lane (vpdpl is ADT divided by total number of lanes)

(b) System average is calculated as total number of crashes / total length of barrier / weighted average ADT per lane (weighted by length)

(c) **Average** is weighted by length of barrier and includes sections of barriers that had no accidents

(d) Low value for all barriers is 0.000E+00 because several sections had no identified crashes during the study

TABLE 4 Crashes in the Control Sections on Interstate 91.

Section	Type	Length (km)	Travel Direction	Police Reported Crashes		Unreported Crashes		Total Identified Crashes	
				Crashes	Crash rate (coll/km/vpdpl)	Crashes	% of Total	Crashes	Crash rate (coll/km/vpdpl)
1	G1	0.39	Southbound	1	1.776E-04	1	50.0%	2	3.552E-04
2	G2	0.32	Southbound	0	0.000E+00	2	100.0%	2	4.228E-04
3	G1	0.58	Northbound	1	1.233E-04	2	66.7%	3	3.699E-04
4	G2	0.63	Northbound	2	2.277E-04	3	60.0%	5	5.691E-04
5	G2	0.26	Northbound	0	0.000E+00	1	100.0%	1	2.220E-04
6	G1	0.24	Northbound	0	0.000E+00	1	100.0%	1	2.775E-04
7	G2	0.74	Northbound	4	2.895E-04	4	50.0%	8	5.790E-04
	G1	1.21	Total	2	1.160E-04 a	4	66.7%	6	3.467E-04 a
	G2	1.95	Total	6	1.834E-04 a	10	62.5%	16	5.028E-04 a

(a) Crash rate weighted by length of barrier section.

TABLE 5 Results of ROADSIDE Analysis.

Predicted Crashes for One Year

Northbound I-91										
Roadside						Median				
Type	Predicted	Police Reported	% Difference	Total Estimated Crashes (a)	% Difference	Predicted	Police Reported	% Difference	Total Estimated Crashes (a)	% Difference
G1	5.44	4	-36.0%	12	54.7%	0.00	0	-	0	-
G2	30.84	23	-34.1%	38	19.5%	1.32	0	-	0	-
CMB	4.23	0	-	0	-	72.78	20	-263.9%	80	9.0%

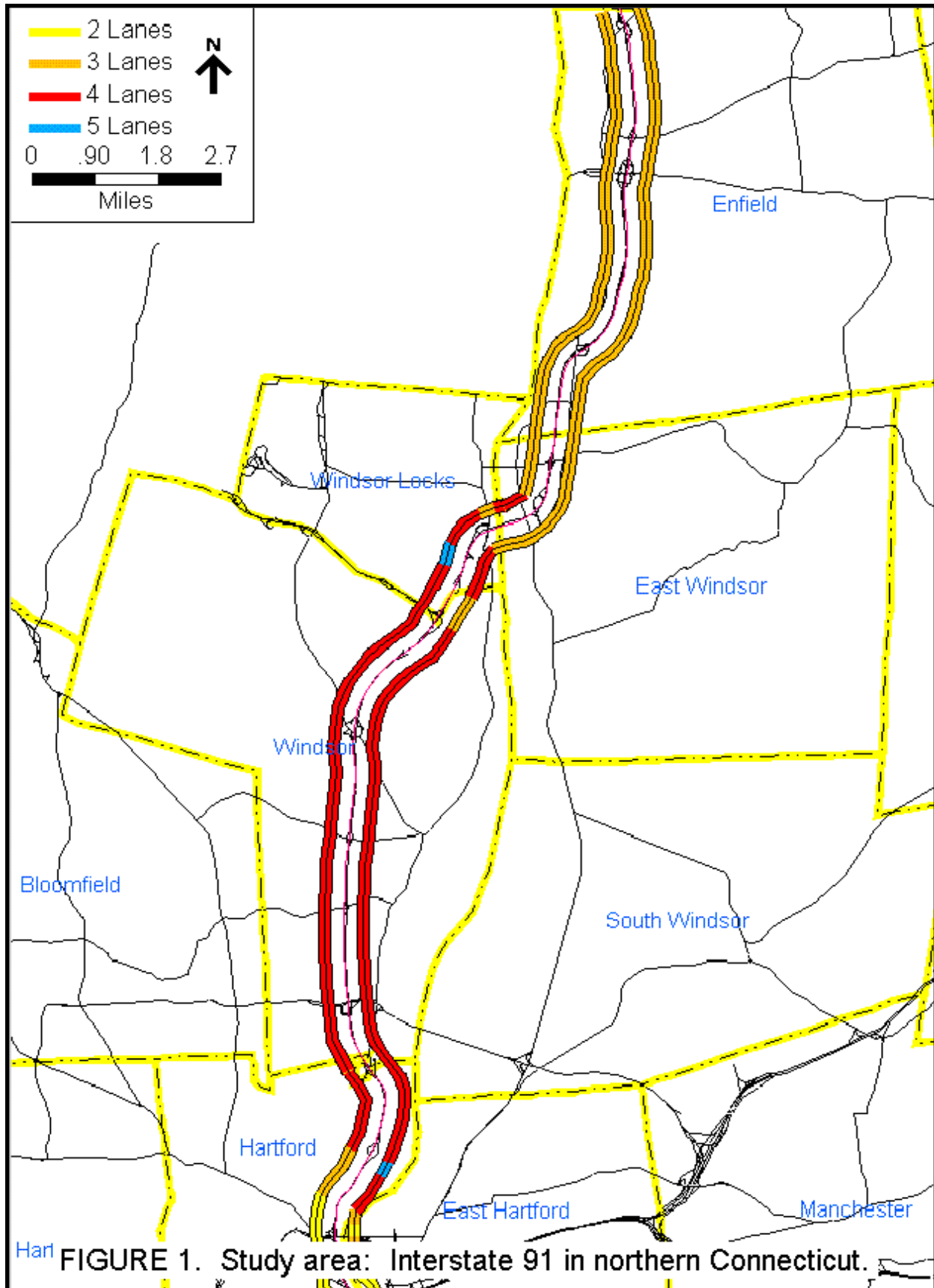
Southbound I-91										
Roadside						Median				
Type	Predicted	Police Reported	% Difference	Total Estimated Crashes (a)	% Difference	Predicted	Police Reported	% Difference	Total Estimated Crashes (a)	% Difference
G1	3.56	4	11.0%	12	70.3%	0.00	0	-	0	-
G2	31.91	18	-77.3%	30	-6.4%	1.53	0	-	0	-
CMB	1.32	0	-	0	-	74.57	28	-166.3%	112	33.4%

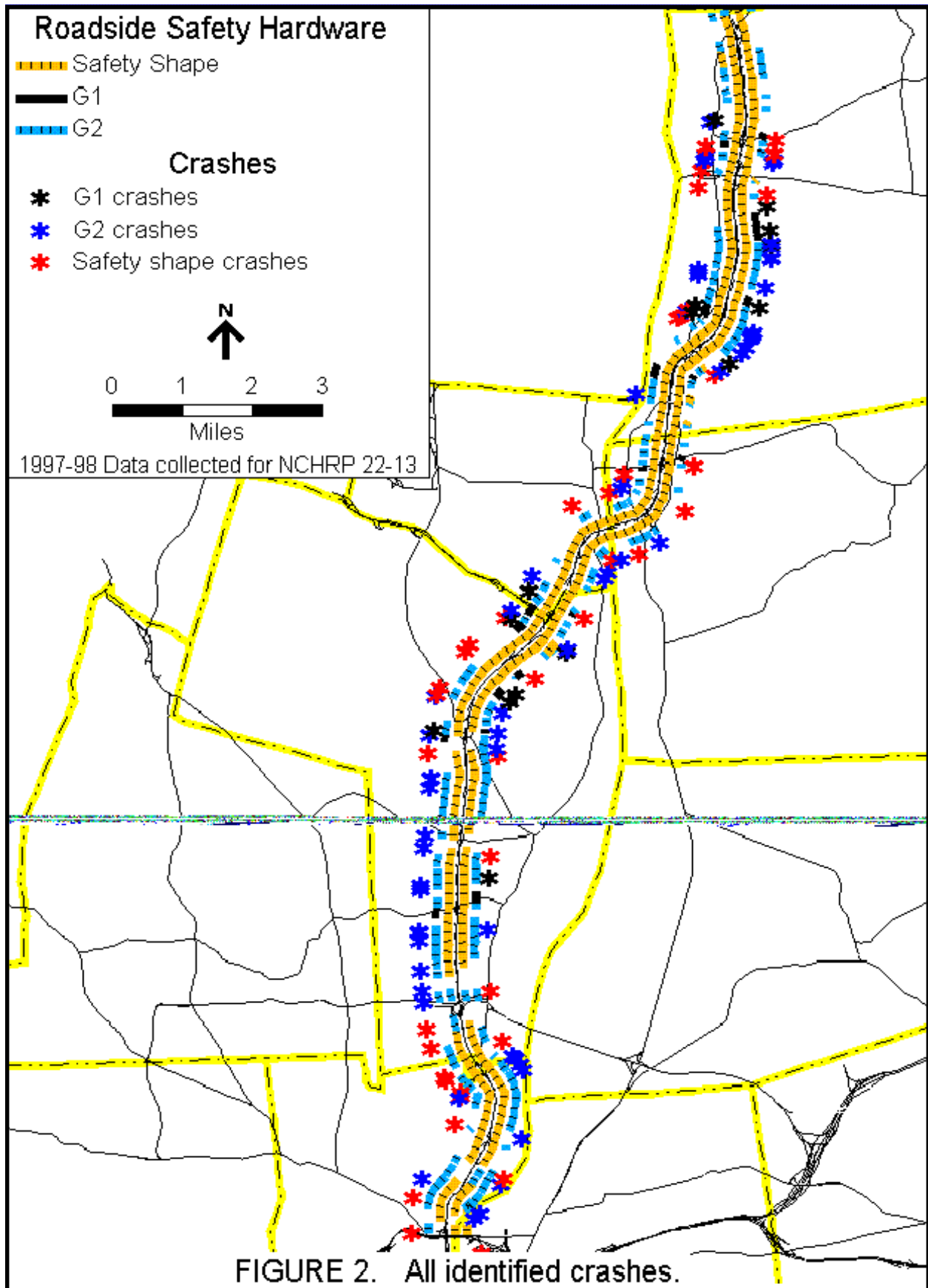
(a) Number of police reported crashes to all crashes at: G1 1-in-3, G2 3-in-5, Safety Shape 1-in-4.

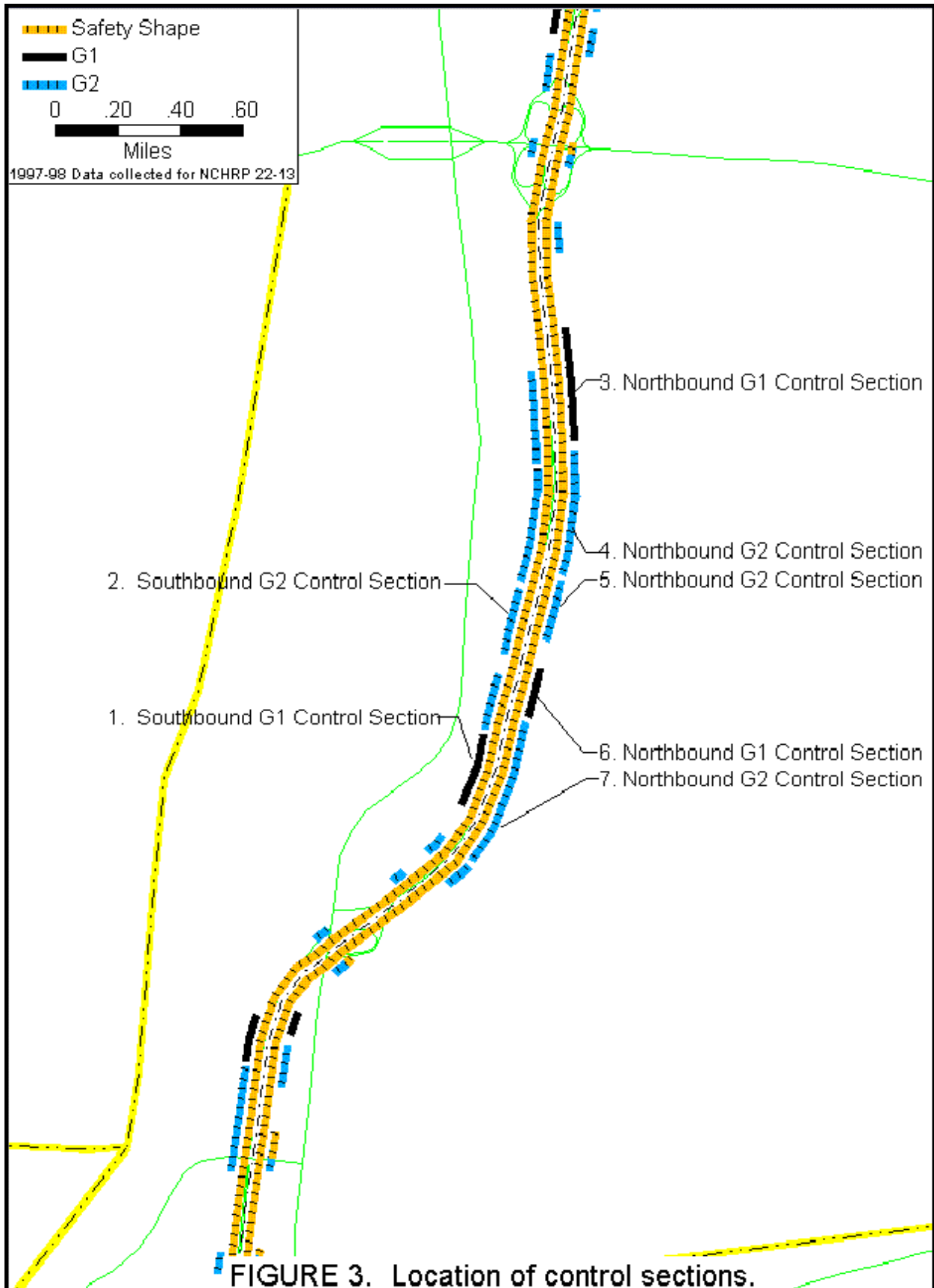
Predicted Crash Rates (collisions/km/vpdpl)

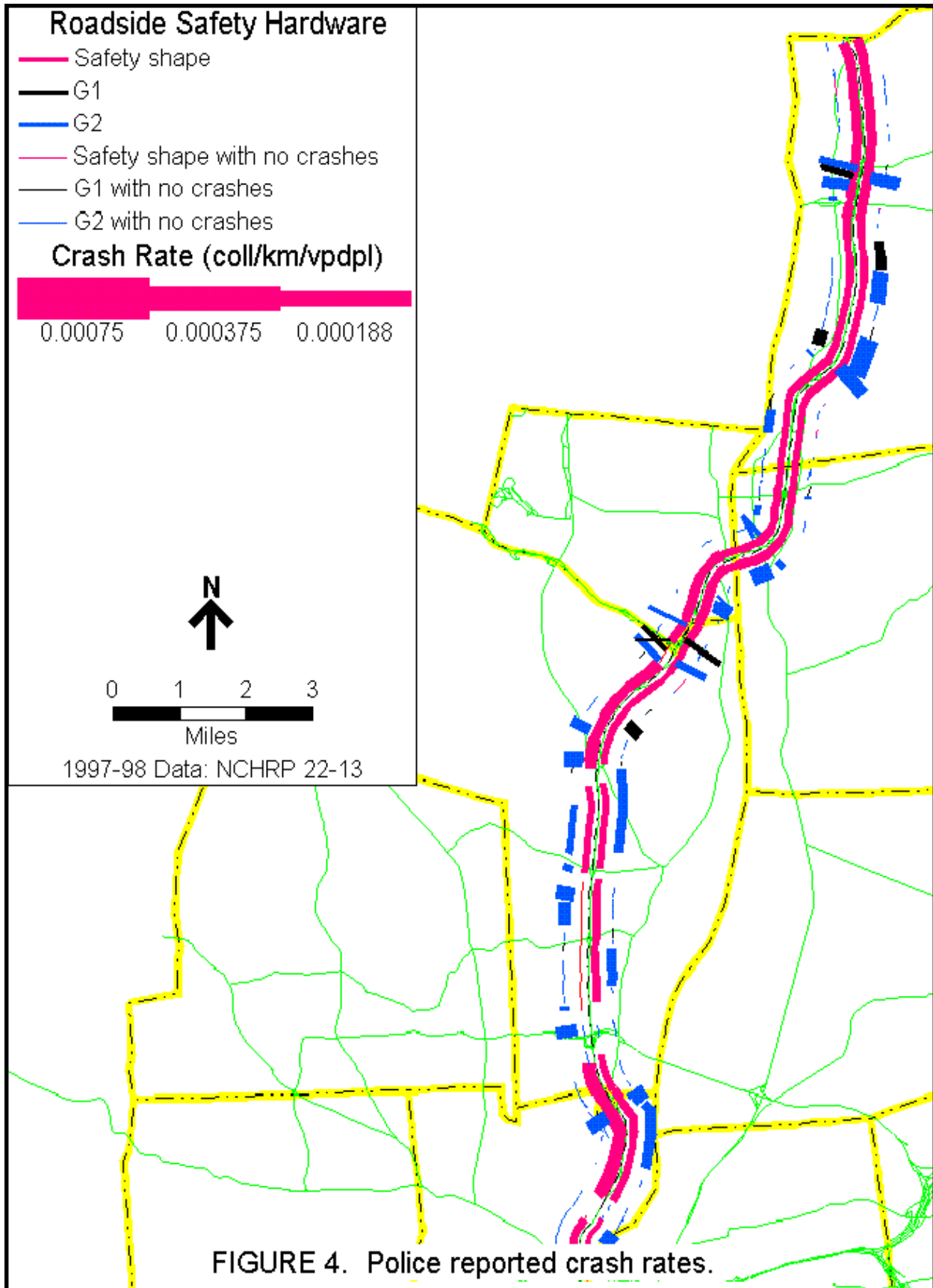
Northbound I-91										
Roadside						Median				
Type	High	Low	Average			High	Low	Average		
G1	6.398E-04	1.591E-04	1.940E-04			0.000E+00	0.000E+00	0.000E+00		
G2	5.417E-04	1.464E-04	1.742E-04			1.781E-04	1.464E-04	1.670E-04		
CMB	4.063E-04	2.519E-04	2.786E-04			6.410E-04	1.717E-04	1.780E-04		

Southbound I-91										
Roadside						Median				
Type	High	Low	Average			High	Low	Average		
G1	3.322E-04	1.591E-04	2.061E-04			0.000E+00	0.000E+00	0.000E+00		
G2	6.512E-04	1.464E-04	1.770E-04			4.120E-04	1.775E-04	1.929E-04		
CMB	2.519E-04	2.519E-04	2.519E-04			3.770E-04	1.717E-04	1.781E-04		









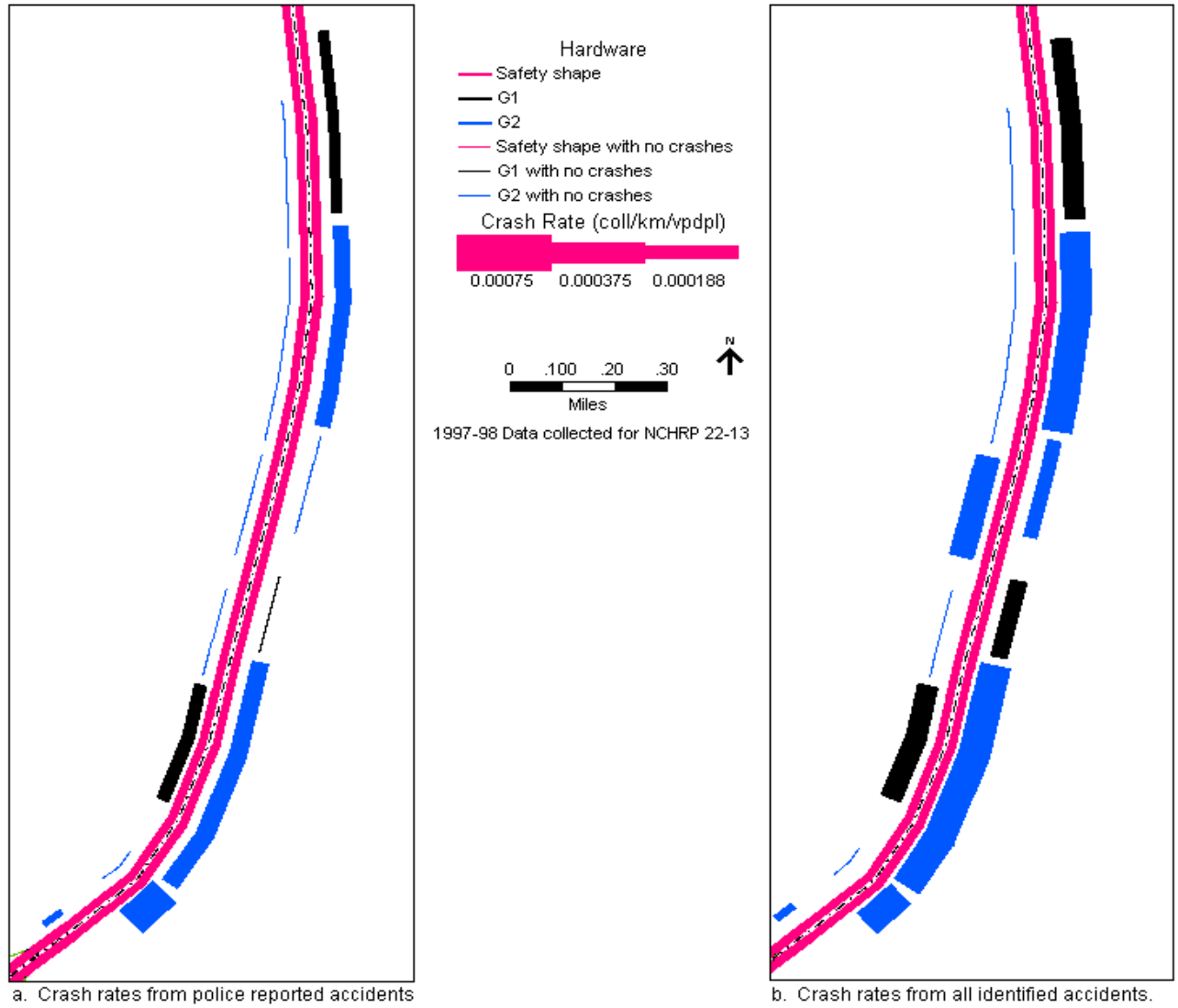


Figure 5. Comparison of crash rates for reported and all crashes.