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Final Report

THE SAFETY AND COST-EFFECTIVENESS OF BRIDGE-APPROACH GUARDRAIL FOR COUNTY STATE-AID (CSAH) BRIDGES IN MINNESOTA

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Bridge-approach guardrail provides protection for vehicles from collision with bridge components, such as the blunt end of the bridge rail or abutment, and other types of run-off-the-road collisions. The primary objective of this research was to determine the average daily traffic (ADT) at which the benefit/cost ratio for the installation of approach guardrail at county-state-aid (CSAH) bridges in Minnesota becomes greater than 1.0. A survey of state transportation agencies found that 26 of 35 responding agencies have policies or guidelines requiring placement of approach guardrail on any bridge if the bridge was built using state funds. Results of the research analyses showed that bridge-approach guardrail was effective at reducing the severity of run-off-the-road crashes occurring on the approach or departure to CSAH bridges. Fatalities and A-injury crashes accounted for only 6 percent of the crashes occurring at bridges with approach guardrail compared to 28.5 percent at bridges without approach guardrail. The subsequent benefit/cost analysis showed that bridge-approach guardrail is cost-effective (i.e., B/C > 1) for CSAH bridges with ADT greater than or equal to 300 vehicles per day (vpd). Overall, approach guardrail has a benefit/cost ratio of approximately 3.5 to 5.5. The researchers recommended that the ADT threshold for approach guardrail on CSAH bridges be set at 400 vpd, which is consistent with previous Mn/DOT standards and AASHTO low-volume local road guidelines. Approach guardrail should be considered on a case-by-case basis for bridges with ADT between 150 and 400 vpd, especially those between 300 and 400 vpd. Placement of approach guardrail at bridges with ADT less than 150 vpd is not cost-effective in most cases.

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EXECUTIVE SUMMARY

Introduction and Objectives

Certain bridge components, including bridge railings, piers, headwalls, and abutments are fixed-objects that are typically very close to the edge of the traveled way and their presence in the clear-zone constitutes a roadside safety hazard. Guardrail and other treatments are often connected to the ends of the rail/parapet to keep vehicles from running-off-the-road (ROR) and striking the less-forgiving ends of the rail or other bridge components or roadside objects. Yet the installation of bridge-approach guardrail on these low-volume roads can add costs and other safety and maintenance problems that may outweigh the proposed benefits.

The FWHA requires bridge-approach guardrail on all NHS roadways, but states are given discretion to develop their own policies or guidelines for non-NHS roadways, such as county state-aid roadways. As of 2004, Mn/DOT required guardrail to be placed on the approach to bridges on the county state-aid bridges if the average daily traffic (ADT) exceeds 750 vehicles per day (vpd), although previous Mn/DOT standards required bridge-approach guardrail on county state-aid bridges with ADTs greater than 400 vpd. The objective of this research was to determine the ADT at which the benefit/cost ratio suggests that installing bridge-approach guardrail provides a positive return on investment (i.e., B/C ratio >1.0) for county state-aid highway (CSAH) bridges in Minnesota. The primary tasks included: review literature, survey other states to determine current practices, analyze crashes at CSAH bridges with approach guardrail versus those without, and analyze the benefits vs. costs for approach guardrail on CSAH bridges.

Literature Summary

The AASHTO *Roadside Design Guide (RDG)* provides guidance in evaluating the need for protection of roadside objects, including bridge rail. Tables in the *RDG* provides minimum clear-zone requirements based on design speed, ADT, and slope. However, the *RDG*, does not specifically address design issues with very low-volume local roads (i.e., ADT ≤ 400), which are of specific interest to the research described here. Perhaps a better tool for addressing design issues on very low-volume local roads is the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)*, which states that roadside clear-zones and safety barriers provide little benefit on low-volume local roads because the probability of striking a roadside object on these types of roads is extremely low when compared to similar higher volume roads.

Nationwide Survey of Current Practice

The researchers conducted a survey of state transportation agencies to determine the state-of-practice for approach guardrail application on county state-aid bridges. Twenty-six of the 35 responding state agencies (74 percent) have policies or guidelines requiring the placement of guardrail or attenuators on bridge approaches if the bridge was built using state funds, regardless of the roadway system. Only Wisconsin, Illinois, and Virginia have policies similar to Minnesota's requiring bridge-approach guardrail on state-aid local highways only where an ADT threshold is exceeded. Six of the respondents indicated that approach guardrail is not required on lower-speed facilities (i.e., ≤ 45 mph).

Bridge-Crash Data Collection

The researchers obtained data for 398 Minnesota CSAH bridges from 10 counties. The 398 bridges were divided into two samples: those with approach guardrail (155) and those without approach guardrail (243). The presence of approach guardrail was confirmed by the county officials, while Mn/DOT's "Pontis" bridge database was queried to obtain other relevant bridge information.

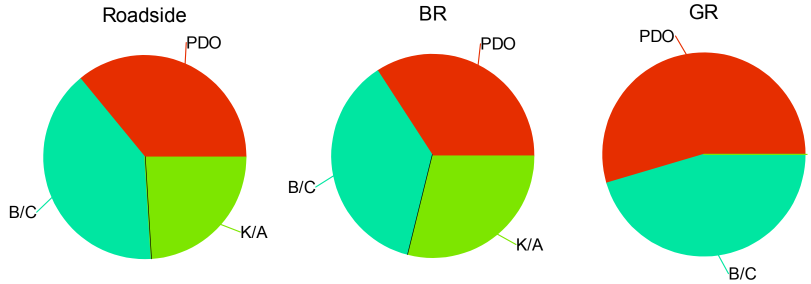
The Minnesota crash database was queried to obtain the crashes that occurred near the 398 bridges included in the sample. The database queries were filtered to include only all single-vehicle fixed-object or ROR crashes that occurred from 1988 – 2002 within approximately 200 ft of the sample bridges. The resulting crash data set included a total of 263 crashes that met the aforementioned criteria, 156 of which occurred at bridges with approach guardrail and the remaining 107 crashes occurred at bridges without approach guardrail.

Analysis of the crash database queries was initially limited because collisions with approach guardrail and all other bridge components were coded into the crash database under a single code (TYPE 31 "bridge piers") and included no further information about the object struck. As a result, the effectiveness of approach guardrail could not be determined using solely the database information. Thus, the researchers reviewed the diagrams and descriptions from the crash reports of the 263 database crashes. A crash was included for further analyses if it involved collision with a bridge component, roadside fixed-object, or other roadside collision and occurred on the approach or departure to one of the sample bridges. The crash report screening process resulted in 96 crashes being deemed useful to the analyses, 47 of which occurred near bridges with approach guardrail, while the remaining 49 crashes occurred at bridges without approach guardrail. Multiple analyses were performed on the data.

Findings

Safety-Effectiveness of Approach Guardrail

The analyses showed that bridge-approach guardrail was effective at reducing the severity (and subsequent costs) of ROR crashes occurring on the approach or departure to CSAH bridges. The proportions of fatal and A-injury crashes were considerably lower when guardrail existed at the bridge. Fatalities or A-injury crashes accounted for only 6 percent of the crashes occurring at bridges with approach guardrail, but accounted for 28.5 percent of the crashes at bridges without approach guardrail – a rate that is 4.5 times greater than at bridges with approach guardrail. As reflected in the following figure, further analysis of the severity of various objects struck showed that zero of the 33 bridge guardrail collisions were fatal or A-injuries compared to 24 percent and 29 percent of roadside and bridge rail collisions resulting in fatalities or A-injuries. These findings were statistically validated by both a chi-square analysis and logistic regression analysis.



Severity vs. Initial Object Struck

Guardrail Protection at All Corners of Bridges versus Approach Corners Only
The analysis showed that approach-side collisions occurred in approximately 62 percent of the sample crashes, while departure-side collisions occurred approximately 34 percent of the crashes (undetermined in 4 percent of the cases). For approach-side crashes at bridges with approach guardrail, the guardrail provided effective attenuation or redirection in 69 percent of the cases with no A-injuries or fatalities. However, departure-side guardrail either did not exist or was too short to be effective in 65 percent of the departure-side collisions at bridges where approach-side guardrail existed and 82 percent of these collisions resulted in either an injury or fatality.

Cost-Effectiveness of Approach Guardrail
The benefit/cost analysis showed that, based on the crash and cost data, bridge-approach guardrail installed at all four bridge corners is cost-effective (i.e., B/C > 1) for CSAH bridges with ADT greater than or equal to 300 vpd and becomes increasingly more cost-effective with increasing ADT. However, bridge-approach guardrail is not cost-effective for CSAH bridges with ADT less than 300 vpd because crashes occur very infrequently. Overall, approach guardrail has a benefit/cost ratio of approximately 3.5 to 5.5 depending on assumptions for traffic growth rate and guardrail costs.

Crash Coding for Collisions with Bridge Components
The Minnesota crash reporting system does not included a specific code for either bridge rail or approach guardrail, rather both were typically included in TYPE 31 "bridge piers," which represented crashes with any component of the bridge, including approach guardrail. A detailed review of the police diagrams/descriptions showed that all of the 67 crashes coded in the database as TYPE 31 were found to be either collision with bridge rail or approach guardrail. Thus, to reduce the ambiguity that exists in the current crash coding system for collisions with bridge components and guardrail, the researchers recommend splitting the current TYPES 31 "bridge pier" and 34 "guardrail" into the following categories: "bridge pier/abutment," "bridge rail", "bridge guardrail (approach or departure)," and "other guardrail (not attached to bridge)."

Recommended Installation for CSAH Bridge-Approach Guardrail
Given the limited number of bridges in the 300 to 400 ADT range, the researchers recommend that the new threshold for approach guardrail on CSAH bridges be set at 400 vpd. In other words, all CSAH bridges with ADT greater than or equal to 400 vpd should have approach guardrail. An ADT threshold of 400 vpd is consistent with previous Mn/DOT standards and AASHTO guidelines. It is recommended that bridges with ADT between 150 and 400 vpd, especially those between 300 and 400 vpd, be reviewed on a case by case basis for guardrail need. Bridges located on horizontal curves and with bridge deck widths less than the approach roadway may warrant guardrail at ADT between 150 and 400 vpd. Placement of approach guardrail at bridges with ADT less than 150 vpd is probably not cost-effective in most cases.

The researchers recommend application of guardrail to all four corners of the bridge rail instead of at the two approach corners only. Guardrail applied at all four bridge corners provides protection for both approach and departure-side events, such as where the vehicle runs off the road to the right after crossing the bridge or runs-off-the-road ahead of the bridge to the left, potentially striking the bridge rail end. Departure-side protection is especially critical on roads with narrow lanes and bridges.

CHAPTER 1:
INTRODUCTION

BACKGROUND

Certain bridge components, including bridge railings, piers, headwalls, and abutments are fixed-objects that are typically very close to the edge of the traveled way. Their presence in the clear-zone constitutes a roadside safety hazard. Guardrail and other treatments, such as attenuators, are often connected to the ends of the rail/parapet to keep vehicles from running-off-the-road (ROR) and striking the less forgiving ends of the rail or other bridge components or roadside objects. Yet the installation of approach guardrail can add costs and other safety and maintenance problems that outweigh the proposed benefits. Beyond the fact that the guardrail itself is a fixed-object within the clear-zone, guardrail is known to promote snow drifting during the winter months providing an additional maintenance and safety concern. Additionally, grass and weeds that grow near the guardrail cannot be cut by traditional lawn mowers requiring county workers to use labor-intensive weed cutting devices around guardrail posts.

The Minnesota Department of Transportation (Mn/DOT) currently requires guardrail to be placed on the approach to bridges on the county state-aid system (CSAH) if the average daily traffic (ADT) exceeds 750 vehicles per day (vpd). Previous Mn/DOT standards required bridge-approach guardrail on highways with ADT greater than 400 vpd. Local traffic engineers, and Mn/DOT staff, suggested that this standard be reviewed since many questioned the benefit versus the cost of the 400 vpd threshold.

After careful consideration, the Standards Committee of Mn/DOT agreed to increase the minimum ADT standard for requiring bridge-approach guardrail to 750 vpd. The 750 vpd value was selected subjectively and represented the upper limit of the next highest ADT range on the design standards chart. In contrast to this standards change, the Mn/DOT Bridge Section recommended lowering the ADT standard to 150 vpd because current standards require that roadways with ADTs greater than 150 vpd be paved, which increases vehicle operating speeds. The Standards Committee has decided to maintain the 750 vpd standard until research is conducted to determine an appropriate ADT value. The Rules Committee in Mn/DOT also looked at this issue and considered:

- Shortening the length of the railing and using a different type of protection;
- Requiring local agencies to pay for approach work costs, including the guardrail;
- The inability of large farm equipment to use the shoulder in areas where guardrail is present; and
- How changes in guardrail or county/township responsibility limits the ability of counties and townships to replace bridges.

In light of the above information and discussion, the Rules Committee accepted the recommendation of the Standards Committee to no longer require bridge-approach guardrail for roadways with less than 750 vpd (anticipated ADT in the design year). However, the discussion and resulting standard change made evident the need for research to determine the conditions (ADT, roadway geometrics, speed, clear-zone) for which the benefits of installing approach guardrail (i.e., improving safety) outweigh the costs. These costs may include installation, general maintenance/repair, and additional maintenance and safety issues associated with snow drifting and vegetation removal.

OBJECTIVE

The objective of this research was to determine the ADT at which the benefit/cost ratio suggests that installing bridge-approach guardrail provides a positive return on investment. In other words, identify the ADT where benefits exceed costs and the benefit/cost ratio exceeds 1.0. This ADT value will be used to establish the threshold/standard for bridge-approach guardrail installation on CSAH roadways in Minnesota.

LITERATURE REVIEW

Current Guidelines and Standards

To protect vehicles from striking the blunt end of the bridge rail, the Federal Highway Administration (FHWA) requires approach guardrail on all National Highway System (NHS) bridges, but does not regulate non-NHS bridges. As a result, states and local agencies are given discretion to develop their own policies or guidelines for the application of approach guardrail on non-NHS roadways. Guidance for determining whether or not approach guardrail should be applied to bridges is provided by two main documents, both published by the American Association of State Highway and Transportation Officials (AASHTO): *Roadside Design Guide* (*RDG*) and *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* (*VLVRDG*).

The *RDG* (*1*) is a leading document for evaluating the need for protection of vehicles from roadside objects, including bridge rail. Table 1.1 is a reproduction of Table 3.1 from the *RDG*, which provides minimum clear-zone requirements based on design speed, ADT, and slope. For example, for a roadway with a design speed of 55 mph and an ADT less than 750 vpd and fore slopes flatter than 1:4, a minimum clear-zone of 12-18 feet is required. However, the *RDG*, does not specifically address design issues with very low-volume local roads (i.e., ADT ≤ 400 vpd), which are of specific interest to the research described here.

Perhaps a better tool for addressing design issues on very low-volume local roads is the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* (*2*), which states that based on research, roadside clear-zones provide very little benefit on low-volume roads. The *VLVRDG* concludes that traffic barriers are not generally cost-effective on roads with very low traffic volumes because the probability of striking a fixed-object on these types of roads is extremely low (compared to similar roadways with higher traffic volumes). Therefore, it is often not economical to provide the same level of roadside hazard protection especially considering the number of centerline miles that possess ADTs of ≤ 400 vpd.

Table 1.1. Clear-Zone Distances in Feet from Edge of Through Traveled Way (*1*)

[U.S. Customary Units]

DESIGN SPEED	DESIGN ADT	FORESLOPES			BACKSLOPES		
		1V:6H of flatter	1V:5H TO 1V:4H	1V:3H	1V:3H	1V:5H TO 1V:4H	1V:6H or Flatter
40 mph or less	UNDER 750	7 – 10	7 – 10	**	7 – 10	7 – 10	7 – 10
	750 – 1500	10 – 12	12 – 14	**	10 – 12	10 – 12	10 – 12
	1500 – 6000	12 – 14	14 – 16	**	12 – 14	12 – 14	12 – 14
	OVER 6000	14 – 16	16 – 18	**	14 – 16	14 – 16	14 – 16
45–50 mph	UNDER 750	10 – 12	12 – 14	**	8 – 10	8 – 10	10 – 12
	750 – 1500	12 – 14	16 – 20	**	10 – 12	12 – 14	14 – 16
	1500 – 6000	16 – 18	20 – 26	**	12 – 14	14 – 16	16 – 18
	OVER 6000	18 – 20	24 – 28	**	14 – 16	18 – 20	20 – 22
55 mph	UNDER 750	12 – 14	14 – 18	**	8 – 10	10 – 12	10 – 12
	750 – 1500	16 – 18	20 – 24	**	10 – 12	14 – 16	16 – 18
	1500 – 6000	20 – 22	24 – 30	**	14 – 16	16 – 18	20 – 22
	OVER 6000	22 – 24	26 – 32 *	**	16 – 18	20 – 22	22 – 24
60 mph	UNDER 750	16 – 18	20 – 24	**	10 – 12	12 – 14	14 – 16
	750 – 1500	20 – 24	26 – 32 *	**	12 – 14	16 – 18	20 – 22
	1500 – 6000	26 – 30	32 – 40 *	**	14 – 18	18 – 22	24 – 26
	OVER 6000	30 – 32 *	36 – 44 *	**	20 – 22	24 – 26	26 – 28
65–70 mph	UNDER 750	18 – 20	20 – 26	**	10 – 12	14 – 16	14 – 16
	750 – 1500	24 – 26	28 – 36 *	**	12 – 16	18 – 20	20 – 22
	1500 – 6000	28 – 32 *	34 – 42 *	**	16 – 20	22 – 24	26 – 28
	OVER 6000	30 – 34 *	38 – 46 *	**	22 – 24	26 – 30	28 – 30

* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear-zone shown in Table 3.1. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirable recovery area are illustrated in Figure 3.2.

Note that the AASHTO *VLVRDG* applies only to roads that are functionally classified as a local road *and* have a design ADT of 400 vpd or less (*2*). This definition is extended to "collectors" that are below the 400 vpd threshold and primarily serve familiar drivers. The *VLVRDG* makes it clear that "local" functional classification of a road is a key element of the definition for the roadways to which the guidelines pertain because it implies a level of driver familiarity with the roadway that is not provided on higher classifications of roads. The 400 vpd ADT threshold for guardrail placement on the approach to bridges was also deemed suitable in NCHRP Report 22-5A, *A User's Guide to Guardrail Warrants for Low-Volume Roads,* as documented in *Transportation Research Circular 416* (*3*). It is significant to note that in 2004, 52 percent of the approximately 5,500 bridges on Minnesota's CSAH roadway network had an ADT of 400 vpd or less.

Relevant Safety Research

Several states have analyzed bridge-approach guardrail through various research efforts, although most of the focus in these studies was placed on crashworthiness of the guardrail/bridge rail connections and end treatments. Very few published literature sources were found to be directly related to the placement-related objectives of this research.

In a late 1970's study for the New Mexico DOT (*4*), Hall found that collisions with guardrail produced severity indices that were approximately 50 percent lower than that of collisions with bridge abutments, which had the highest severity index of all fixed-object collisions that were examined. Crashes with guardrail accounted for only 1.8 percent of all fatal crashes. As a result, it was suggested that the addition of guardrail to protect an abutment or bridge would reduce the crash severity by 50 percent. Hall also found that bridges were the most common location for a guardrail crash to occur (28 percent of all reported guardrail crashes in New Mexico), likely due to the fact that bridges were the most common location for guardrail installation with 31 percent of all installations.

In 1989, the Iowa DOT conducted a study examining the application of bridge-approach guardrail on primary roads (*5*). At this time, 65 percent of Iowa's bridge-crash fatalities were due to impacts with unprotected bridge rail/abutments. After determining an array of potential benefits and costs, a benefit/cost analysis was completed using an early version of AASHTO's ROADSIDE software program, which generated linear relationships between the benefit/cost ratio and ADT at various lateral offsets for the guardrail. The Iowa study found the break-even benefit/cost ratio (i.e., b/c = 1.0) for the application of bridge-approach guardrail to apply to roadways with 1,400 vpd and a guardrail offset of two feet from the edge of pavement. Higher traffic volumes would increase the expected benefit/cost ratio, while higher guardrail offsets would decrease the benefit/cost ratio. The report suggests that benefit/cost ratios as low as 0.8 are still acceptable values for upgrading.

More recently, a study by Wolford and Sicking found little need for guardrail for protection of embankments and culverts when the ADT was less than approximately 500 vpd, regardless of other variables (*6*).

CHAPTER 2:
SURVEY OF NATIONWIDE STATE AGENCY PRACTICE

A critical extension of the literature review was a survey of current agency practice pertaining to application of bridge-approach guardrail on low-volume state-aid (or similar) local facilities. The researchers developed an Internet-based survey questionnaire and administered the survey to members of the AASHTO Highway Subcommittee on Traffic Engineering, representing all 50 state departments of transportation (DOTs). The survey consisted of seven concise questions and relevant state DOT personnel were contacted via email in January 2004 and asked to respond to the Internet survey. The survey responses were automatically submitted via email to the research staff. A copy of the survey instrument can be found in Appendix A.

The goal of the survey was to determine the procedures of state DOTs pertaining to the use of bridge-approach guardrail. Of particular interest was the basis for determining whether approach guardrail should be applied to bridges on low-volume local roads. The primary survey questions included:

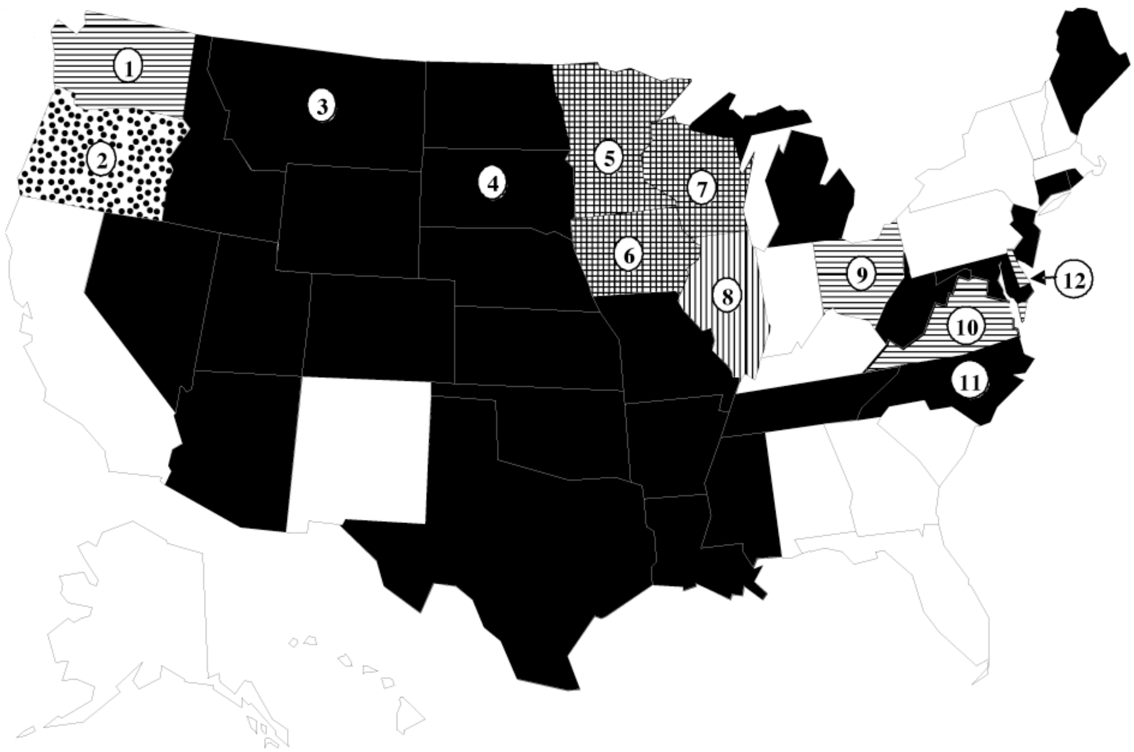
- Is ADT used to determine whether or not to place guardrail on the approach to bridges on local roads, and if so, what is this ADT value and how was it chosen?
- If ADT is not used, what is the basis for placement of guardrail on bridge approaches for local roads?
- Do other factors play a role in the decision to place/not place bridge-approach guardrail?
- Are treatments other than guardrail used to shield the bridge rail?

Detailed survey responses provided by the state DOTs and the FHWA are presented in Appendix B. A summary of the survey findings is provided in the following section.

SURVEY FINDINGS

Criteria for Application of Approach Guardrail on Local State-Aid Bridges

Figure 2.1 summarizes the state-by-state criteria for approach guardrail on local state-aid bridges. Twenty-six of the 35 responding state agencies (74 percent) have policies or guidelines requiring the placement of guardrail or attenuators on bridge approaches if the bridge was built using state funds, regardless of the roadway system. The general belief among these agencies was that the bridge rail or parapet ends are fixed-object hazards within the clear-zone and therefore traffic must be shielded. This complies with the clear-zone requirements in the AASHTO *Roadside Design Guide* (*1*), which was cited by many agencies as the basis for their policy or guideline. Furthermore, nearly every agency indicated that guardrail placement was dictated by agency policy rather than a guideline, although some agencies grant exceptions to their guardrail policy, as noted in Figure 2.1.



Legend:

- All state-aid bridges protected (n = 26)
- ADT and Speed Threshold (n = 3)
- ADT threshold (n = 2)
- Decision made on case-by-case basis (n = 1)
- Speed Threshold (n = 3)
- No Response (n = 15)

Notes:

1. Historic bridges or urban routes 35 mph or less may be exempted
2. ADT and operating speed are used to make bridge-approach guardrail decisions for low-volume state and local roads.
3. Very low-volume roads or low-speed urban facilities may be exempted on a case-by-case basis, but rarely is this done.
4. ADT < 150 requires only turned down guardrail treatment connected directly to bridge
5. ADT < 750 doesn't require guardrail; design speed 40 mph or less may also be exempted
6. Guardrail not needed if speed limit is 35 mph or less; also exempted are bridges with ADT < 200, bridge wider than 24 ft, on tangent, and benefit/cost ratio < 0.8
7. ADT < 300 doesn't require guardrail; also exempted are curbed urban roads with design speeds 45 mph or less
8. ADT < 150 doesn't require guardrail (tangent alignment only); approach guardrail required for all bridges on curves
9. Speed limit 45 mph or less doesn't require guardrail
10. ADT < 400 doesn't require guardrail; factors such as speed, crashes, paving, cost, and bridge rail condition are also considered
11. Very low-volume roads or low-speed urban facilities may be exempted on case-by-case basis, but is generally not done
12. Design speeds 35 mph or less use a tapered-down parapet; guardrail must be applied if slope steeper than 3:1

Figure 2.1. Criteria for Application of Approach Guardrail on Local State-Aid Bridges

Four of the 35 responding state agencies (Minnesota, Wisconsin, Illinois, and Virginia) require bridge-approach guardrail on state- or federal-aid local facilities only at locations where an ADT threshold is exceeded (Figure 2.1). Wisconsin and Virginia noted that their respective ADT threshold values were based on the guidelines in the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400),* which suggests that the use of guardrail for protection of fixed-objects is generally not cost-effective for roadways with ADT ≤ 400 vpd (*2*).

Six of the responding agencies (Minnesota, Wisconsin, Iowa, Washington, Ohio, and Delaware) indicated that lower-speed facilities (i.e., speeds equal to or less than 45 mph) do not require approach guardrail. Oregon DOT indicated that the decision to place approach guardrail for non-National Highway System bridges is made by the supervising engineer on a case-by-case basis, considering factors such as ADT and operating speed. Some agencies indicated that other factors may also be considered when determining whether or not to place approach guardrail on local state-aid bridges, including horizontal curvature, bridge width, and benefit/cost analysis. These additional factors are noted in Figure 2.1.

Use of Protective Treatments Other than Guardrail

The minimum length of an NCHRP 350-compliant section of approach guardrail with proper transition and end treatment is approximately 75 feet. Certain cases exist where there is insufficient space to place a minimum section of guardrail on a bridge approach. This may occur when a driveway, roadway, or immovable structure is located very near the bridge and movement or realignment is not economical. Where space is limited, some agencies opt to use treatments such as crash attenuators directly affixed to the bridge rail, while other agencies continue to use a shortened or curved/flared section of guardrail due to the expense of the attenuator. Figure 2.2 displays state agency use of attenuators where insufficient guardrail space exists. Responses were rather evenly split between attenuator versus a minimal or modified section of guardrail when insufficient guardrail space exists.

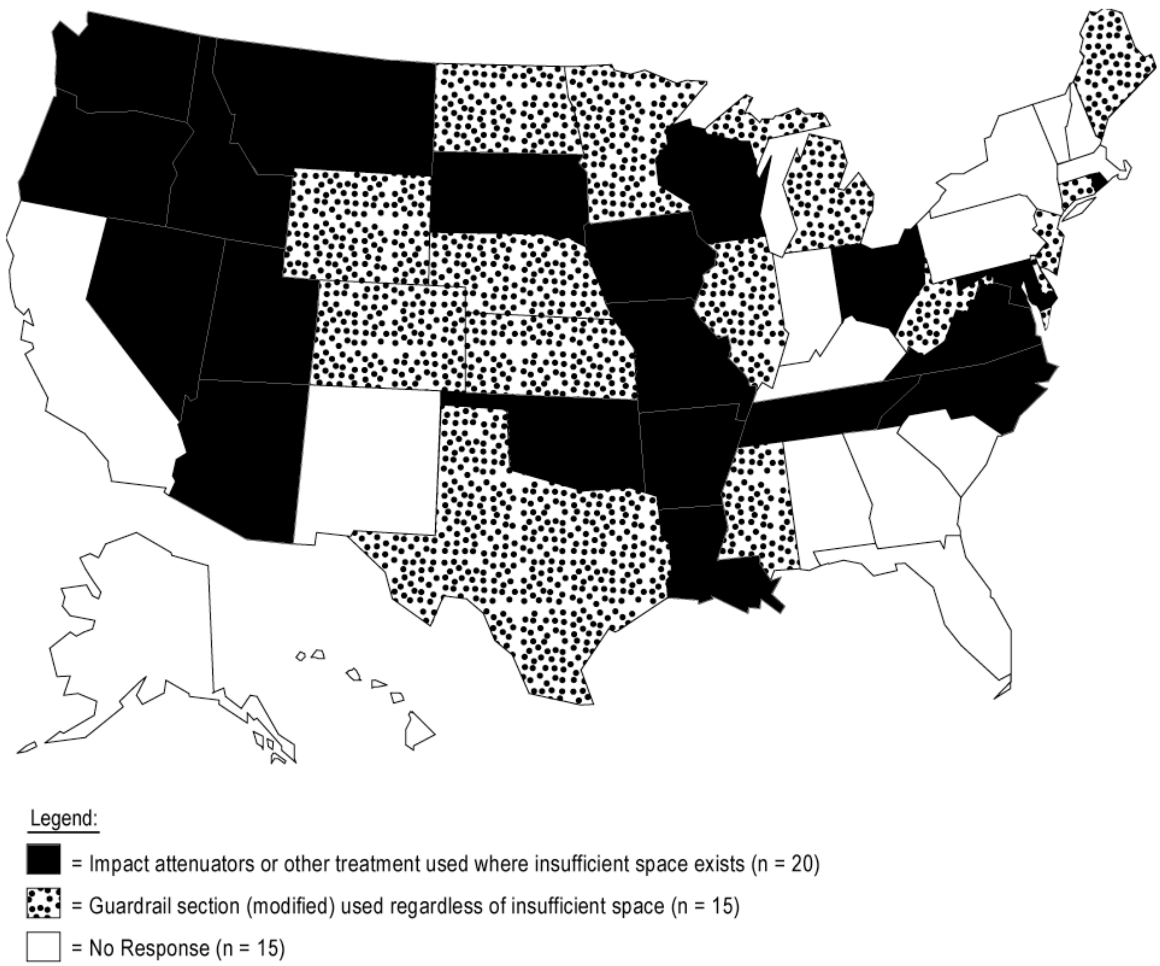


Figure 2.2. Treatments Used Where Insufficient Guardrail Space Exists

Iowa Procedure for Determining Need for Bridge-Approach Guardrail

The Iowa Department of Transportation has developed an instructional memorandum explaining the procedure for determining the need for traffic barriers at roadway bridges and culverts, which is perhaps the most comprehensive procedure of its kind among state DOTs. A copy of this procedure is provided in Appendix C. Note that a scoring system has been developed to determine the type of guardrail system required. The memo states that design exceptions to not install guardrail at bridges or culverts will be considered if the following conditions exist:

1. Current ADT at structure is less than 200 vpd,
2. Structure width is 24 feet or greater,
3. Structure is on tangent alignment, and
4. Benefit/cost Ratio is less than 0.80.

The memo goes on to say that other obstructions, within the right-of-way and clear-zone, should be reviewed for removal, relocation, and installation of a traffic barrier or the “do nothing” option based on a cost-effectiveness approach.

CHAPTER 3:
ANALYSIS METHODOLOGY

One of the major data analysis tasks of this project involved comparison of crashes occurring at bridges both with and without approach guardrail. This task was important for two reasons:

- Inference could be made as to the relative safety effects of using guardrail on bridge approaches for a number of different bridge/roadway characteristics; and
- Results could be used in a benefit/cost analysis.

To perform such a safety analysis, the researchers deemed it necessary to collect crash data for two discrete populations of bridges on Minnesota CSAH roadways:

- Crashes occurring at bridges WITH guardrail on the approach; and
- Crashes occurring at bridges WITHOUT guardrail on the approach.

Examples of typical CSAH bridges with and without guardrail are shown in Figures 3.1 and 3.2, respectively.

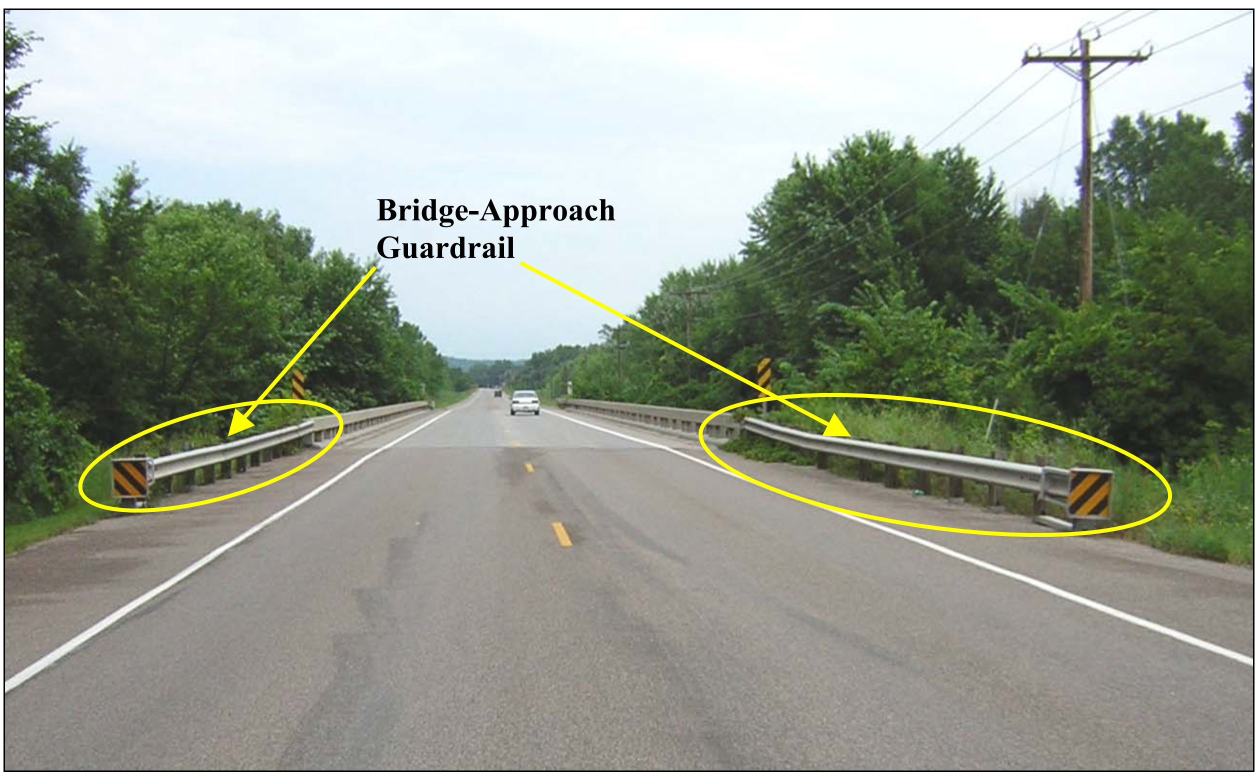


Figure 3.1. CSAH Bridge With Approach Guardrail

Figure 3.2. CSAH Bridge Without Approach Guardrail

CSAH BRIDGE DATA

Because of the relatively few number of crashes that occur at CSAH bridges, researchers deemed it appropriate to create a sample of at least 100 CSAH bridges for each of the two bridge populations. The belief was that 100 bridges would provide at least 100 crashes for each population, thereby providing a sample size large enough for statistical interpretation.

Development of Bridge Sample Populations and Collection of Inventory Data

In order to identify CSAH bridges for inclusion in one of the two sample populations, it was necessary to identify whether or not approach guardrail existed on the bridge. Identifying the existence of approach guardrail on CSAH bridges turned out to be a substantial challenge. The researchers determined early in the project that sufficient approach guardrail information for CSAH bridges could not be obtained from Mn/DOT's "Pontis" bridge inventory database. Other options, such as reviewing roadway inventory video logs or reviewing construction plans, were also ruled out due to unavailability of such records for the CSAH roadway system. As a result, it was determined that approach guardrail information for CSAH bridges would need to be obtained directly from the counties.

An initial step in the collection of bridge data occurred on July 20th and 21st of 2004 when University of Wisconsin-Madison researchers met with engineering personnel from four Minnesota counties: Fillmore, Olmsted, Goodhue, and Dakota. These counties were chosen based on their availability of appropriate data and because they provided a suitable balance of rural and urban/suburban bridges with a broad range of traffic volumes. The meetings provided the researchers with necessary data pertaining to CSAH bridge-approach guardrail, including;

- Complete lists of CSAH bridges with approach guardrail (by bridge number);
- Current costs associated with guardrail installation on bridges; and
- Issues and challenges faced by the counties with regards to placing approach guardrail on CSAH bridges.

Based on these meetings, researchers developed a plan for telephone or email correspondence with engineering personnel from numerous other Minnesota counties to obtain similar information. By October 2004, detailed CSAH bridge data had been received from a total of ten Minnesota counties: Anoka, Crow Wing, Dakota, Fillmore, Goodhue, Lyon, Mower, Olmsted, Rock, and Watonwan. Other counties were contacted but were unable to provide the necessary data.

The ten previously listed Minnesota counties provided the researchers with a list of 155 CSAH bridge identification numbers for bridges *with* approach guardrail. Using this list of 155 bridge ID numbers, Mn/DOT's Pontis bridge inventory database was queried to obtain additional information pertaining to each of the bridges for use in the crash analysis. Such relevant data included reference point, location, year built, max span length, number of lanes, functional class, and ADT. A sample of the resulting Pontis query is shown in Table 3.1.

A second Pontis query was generated to form a comparison sample of CSAH bridges *without* approach guardrail for each of the ten counties. This resulting group of 243 CSAH bridges was generated by querying all CSAH bridges for each of the ten counties excluding the 155 generated in the first query, culverts, and structures without a deck. The purpose of generating the comparison group in this manner was to provide a set of CSAH bridges similar to the 155 generated in the first query with the primary physical difference being the lack of approach guardrail. The full Pontis bridge inventory data for all 398 CSAH bridges can be found in Appendix D.

Table 3.1. Example of CSAH Bridge Data Obtained from Pontis Database

Br Num	Ref Point	Facility	County No.	Location	Yr Built	Lanes	Functional Class	ADT Total
55516	005+00.500	CSAH 7	55	2.1 MI N OF JCT TH 52	1968	2	06-RUR/MINOR ART	940
55521	003+00.710	CSAH 7	55	0.4 MI N OF JCT TH 52	1971	2	06-RUR/MINOR ART	940
55512	001+00.750	CSAH 8	55	0.7 MI N OF JCT CSAH 6	1966	2	08-RUR/MINOR COLL	1,000
6787	006+00.490	CSAH 17	67	1.0 MI S OF JCT TH 90	1955	2	07-RURAL COLL	560
67538	016+00.360	CSAH 3	67	0.3 MI N OF JCT CSAH 8	1999	2	07-RURAL COLL	470
67524	018+00.805	CSAH 4	67	0.7 MI W OF JCT CSAH 3	1984	2	07-RURAL COLL	1,450
L2033	007+00.950	CSAH 5	67	1.9 MI E OF JCT CSAH 6	1956	2	07-RURAL COLL	350
83513	003+00.450	CSAH 12	83	1.4 MI N OF JCT CSAH 10	1978	2	07-RURAL COLL	255
90340	003+00.000	CSAH 18	83	0.9 MI N OF JCT CR116	1920	2	08-RUR/MINOR COLL	40
90343	006+00.760	CSAH 19	83	0.4 MI N OF JCT CR119	1923	2	08-RUR/MINOR COLL	135

Bridge Characteristics

Upon obtaining the Pontis data for the 398 CSAH bridges, the researchers were able to summarize and compare the characteristics of the bridges in each sample population. Figure 3.3 provides a map of the bridge locations. Figure 3.4 shows the number of bridges per county both with and without approach guardrail.

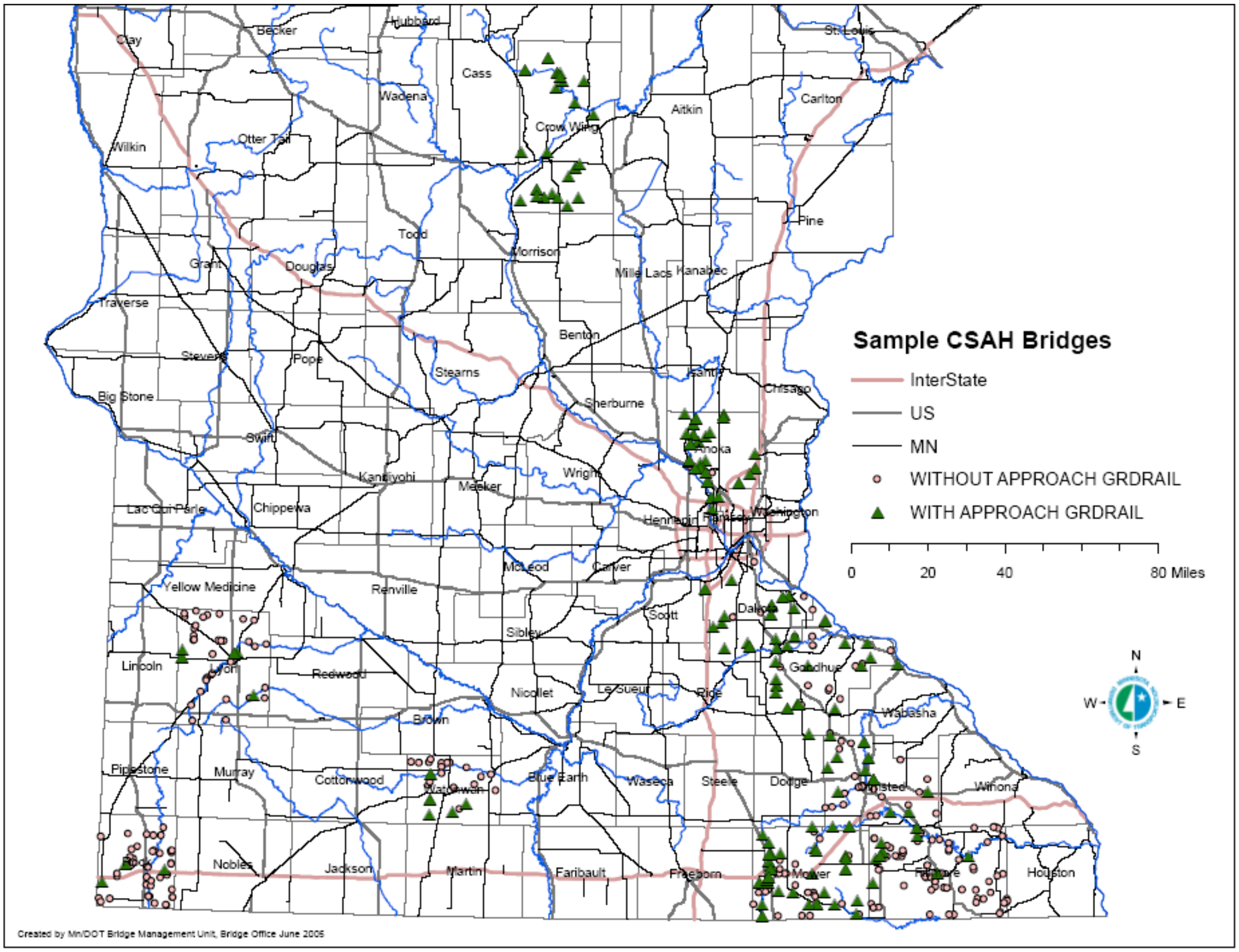


Figure 3.3. Map of CSAH Bridges Used in the Analysis

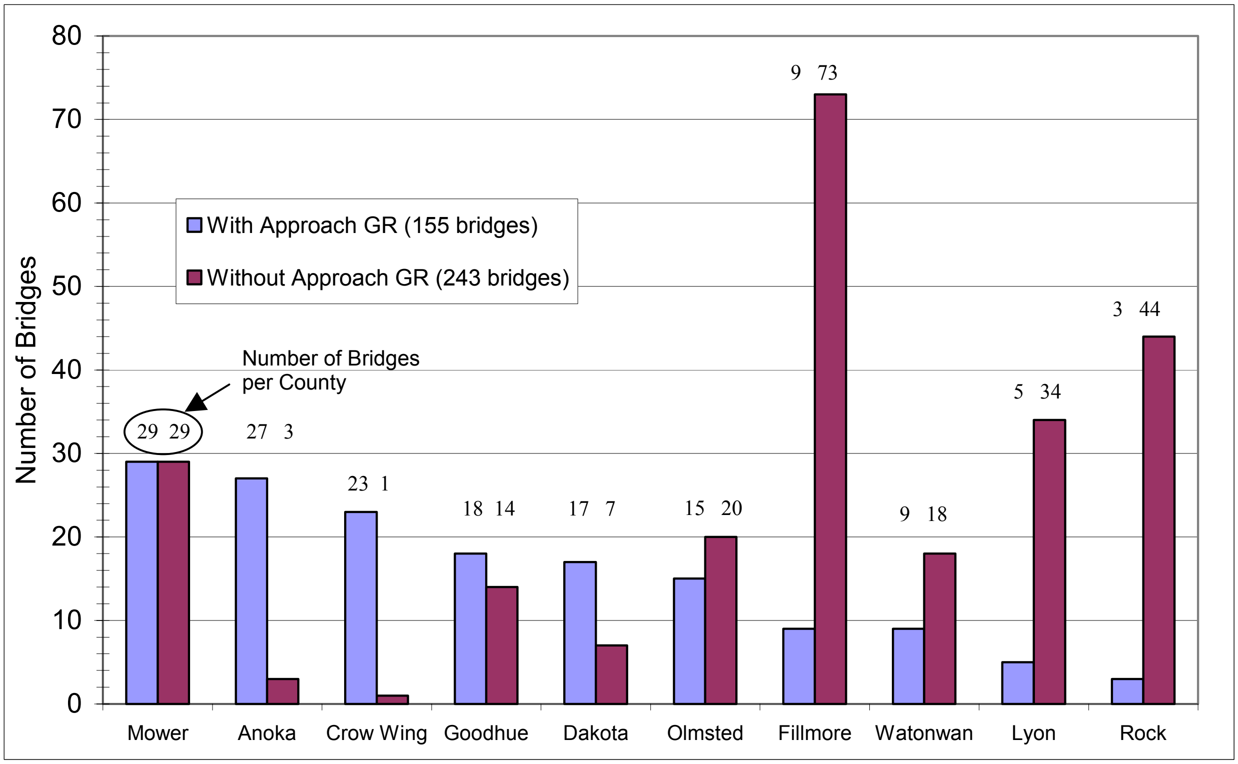


Figure 3.4. Number of Bridges by County

The counties shown in Figure 3.4 are ordered from the most to least number of bridges with approach guardrail. It can be observed that the counties with the greatest number of bridges *with* approach guardrail (mostly suburban counties) typically have the fewest number of bridges *without* approach guardrail and vice-versa. This is expected as the suburban counties have higher traffic volumes and thus a greater percentage of bridges with guardrail on the approach, since guardrail placement on CSAH bridges is typically based on ADT.

Perhaps a more useful representation of the two bridge sample populations is separation by ADT, as displayed in Figure 3.5. With some exceptions, ADT data reported in Pontis were measured by the counties between 2001 and 2003. To provide consistency, these ADT values were converted to 2004 ADT prior to the analyses using each county's estimated 2004 traffic growth rate. As expected, the sample of bridges with approach guardrail was shifted toward the higher ADT ranges while the bridges without approach guardrail generally fell into the lower ADT ranges. The median ADT was 1,320 vpd with a range from 42 to 41,524 vpd for the 155 bridges with approach guardrail and 325 vpd with a range from 16 to 27,785 vpd for the 243 bridges without approach guardrail. It is interesting to note that 57 of the bridges *without* approach guardrail have ADTs exceeding the current CSAH guardrail warrant of 750 vpd. It is likely that many of these bridges were built prior to any ADT requirement for approach guardrail and were thus grandfathered in.

Figure 3.6 displays the percent of bridges versus number of lanes on the bridge. The figure shows that a majority of the bridges were two-lane bridges. With very few exceptions, the bridges in both populations accommodated two-way traffic. Also with very few exceptions, the bridges in both populations were water crossings.

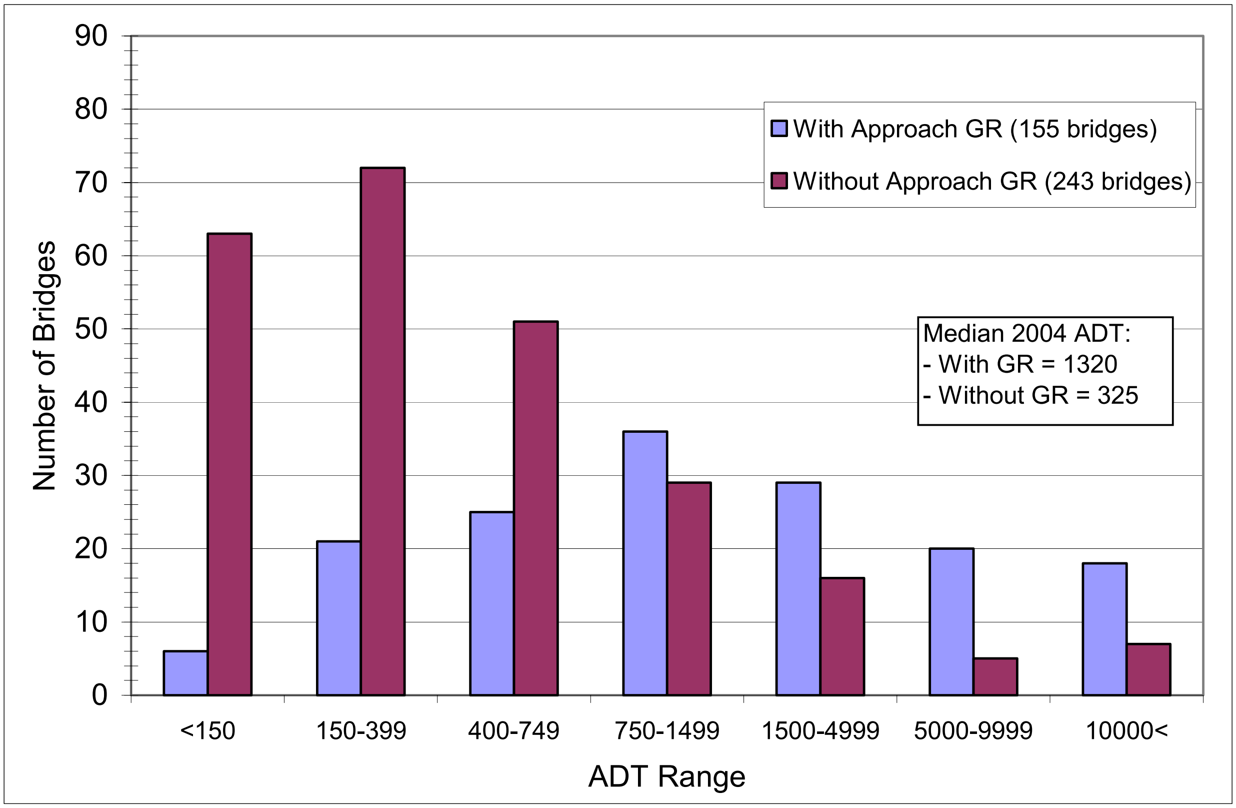


Figure 3.5. Number of Bridges by ADT Range

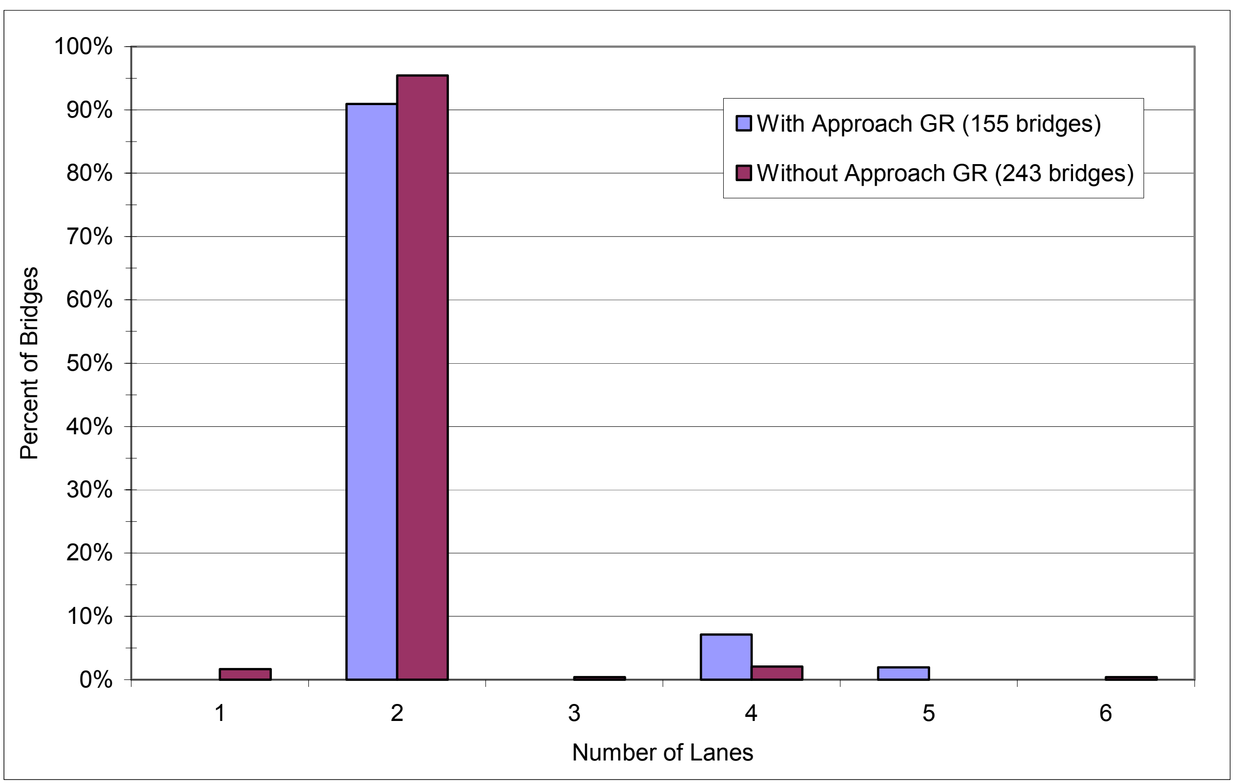


Figure 3.6. Percent of Bridges by Number of Lanes

Further separation by functional class and bridge age are shown in Figures 3.7 and 3.8, respectively. Separation by functional class in Figure 3.7 shows that 83 percent and 96 percent of the sample bridges with and without guardrail, respectively, are on roadways classified as rural. Figure 3.8 shows that the bridges with approach guardrail are slightly newer with a median age of 34 years, compared to 44 years for those without approach guardrail.

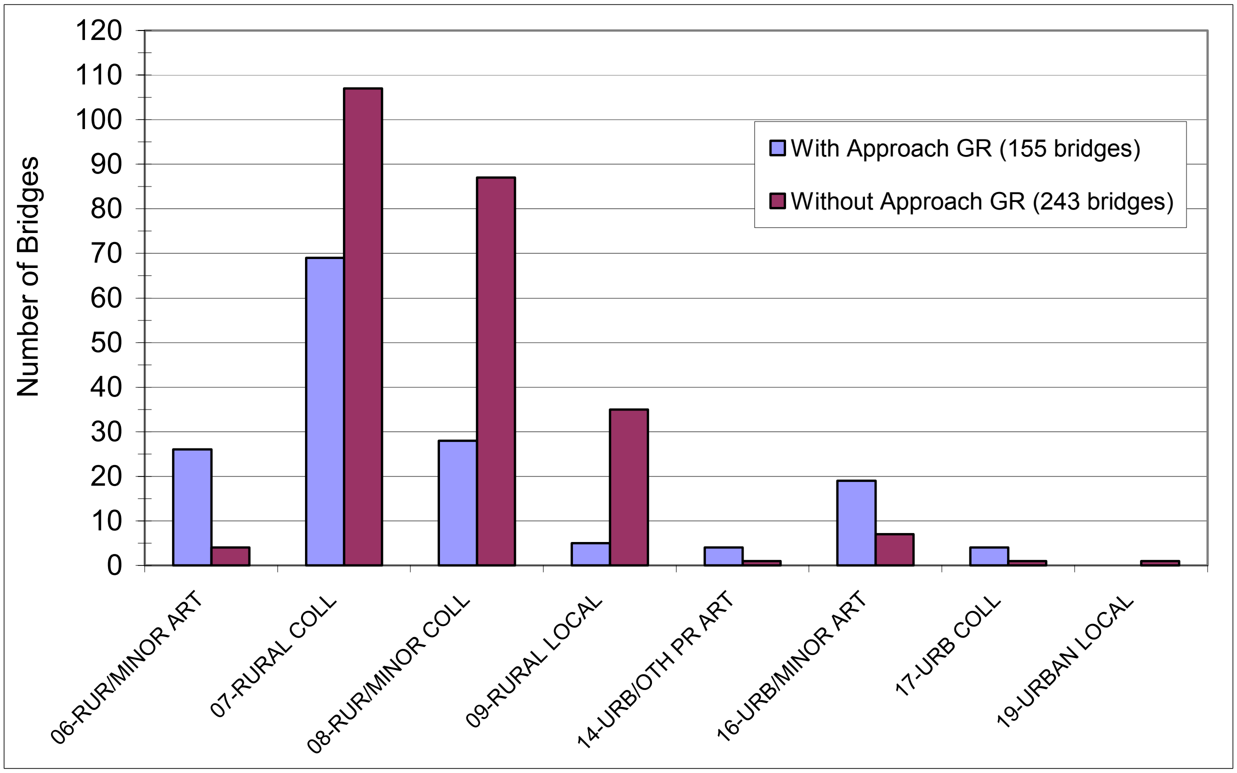


Figure 3.7. Number of Bridges by Functional Class

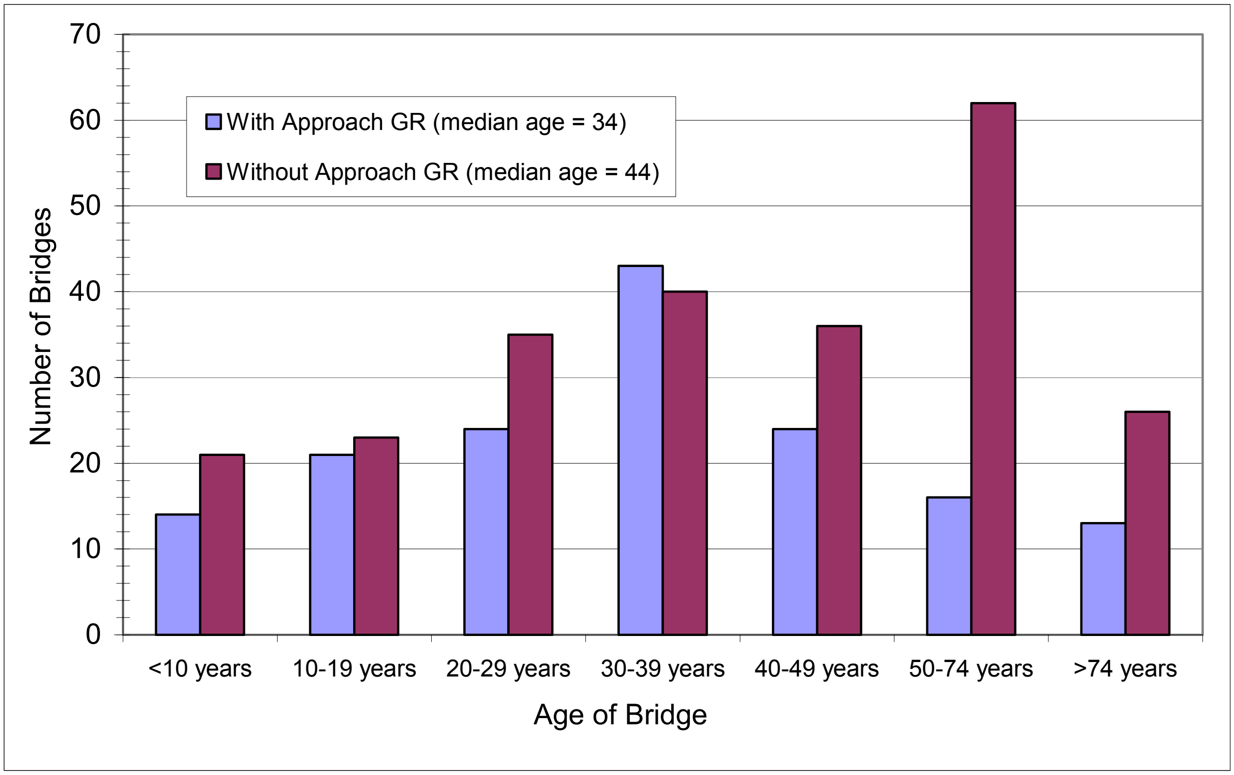


Figure 3.8. Number of Bridges by Age of Structure

COLLECTION OF CRASH DATA

Initial Queries of Minnesota Crash Database

After determination of the relevant bridge characteristics for the 398 sample bridges, the roadway and linear reference point data obtained from the Pontis queries were used by the researchers to collect the associated crash data for the bridges. Two queries were obtained from the Mn/DOT crash database:

- Crashes that occurred near the 155 bridges *with* approach guardrail, and
- Crashes that occurred near the 243 bridges *without* approach guardrail.

Each query included all crashes from 1988 – 2002 that occurred on the specified CSAH highway within ± 1 mile from each bridge's reference point (from Pontis). The 15-year analysis period was chosen to obtain the largest sample of crashes possible, recognizing the infrequency at which collisions occur near bridges. The effect of both changing traffic volumes and changes to the crash reporting practices over the 15-year analysis period should be offset by the fact that both bridge sample populations were taken from the same ten counties and thus any temporal effects are expected to be roughly the same for both bridge populations.

Crash Data Filtering

The initial crash database queries included information for crashes of all types that occurred within ± 1 mile from the bridges, which resulted in approximately 10,250 crashes at bridges with approach guardrail and 5,150 crashes for bridges without approach guardrail.

Further screening of the crash data was thus necessary to obtain only "target" crashes occurring near the bridges that would likely be affected by the presence or absence of approach guardrail.

The target crashes included all fixed-object and run-off-the-road crashes occurring in the general vicinity of the bridge. The researchers used the following two criteria to further filter (i.e., select) crashes from the initial crash queries:

- Crash occurred within 0.04 miles (approximately 211 ft) of the bridge reference point (this was extended out further for crashes involving TYPE 31 "bridge piers" to aid against slight inaccuracies in the reference point coding); and
- Crash was one of the following types: collision with light pole (TYPE 24), collision with utility pole (25), collision with sign structure or post (26), collision with mailboxes and/or posts (27), collision with other poles (28), collision with tree/shrubbery (30), collision with bridge piers (31), collision with median safety barrier (32), collision with crash cushion (33), collision with guardrail (34), collision with fence (35), collision with culvert/headwall (36), collision with embankment/ditch/curb (37), collision with building/wall (38), collision with rock outcrops (38), collision with other fixed-object (41), collision with unknown type of fixed-object (42), overturn/rollover (51), submersion (52), other type of crash (90) (single vehicle crashes only).

The filtering task was very labor-intensive as each of the more than 15,000 crashes in the initial query was manually examined to determine its applicability to our analysis based on the above criteria. The resulting crash data set included a total of 263 crashes occurring between 1988 and 2002 that met the aforementioned criteria. Of the 263 crashes, 156 crashes occurred at bridges *with* approach guardrail and 107 crashes occurred at bridges *without* approach guardrail. Detailed information on all 263 crashes can be found in Appendix E.

For each bridge population, about half of the crashes were coded in the database as having occurred on dry pavement, while the other half occurred on wet/snowy/icy pavement. Furthermore, although wet or icy pavement conditions are typically associated with a higher frequency of crashes, such conditions do not necessarily cause the crashes to be more severe. Because the analyses performed here were largely focused on crash severity rather than overall frequency, the researchers felt it was not necessary to further analyze the effect of pavement condition.

Police Crash-Report Data

The filtered crash data from the database queries provided a general overview of the crashes occurring near CSAH bridges. However, the researchers quickly determined that a detailed analysis of the effectiveness of approach guardrail could not be determined solely from the crash database information. This was because approach guardrail and all other bridge components occurring during the analysis period were coded in the crash database as TYPE 31 "bridge piers" and no further information was listed that would allow for determination of the actual object struck. To resolve this problem, researchers obtained Mn/DOT crash reports for most of the 263 bridge crashes that were identified from the initial database queries. The researchers then performed a detailed manual review of each crash report to gather necessary information that was not available in the database, including the object struck, the location of the collision with respect to the bridge, and the nature of the collision. The data obtained from the police crash-reports were then used to perform a detailed analysis of the safety effectiveness of bridge-approach guardrail. Detailed information about the analysis of police crash-report data is described later in Chapter 5. The crash report data were also used in the benefit/cost analysis, which is fully discussed in Chapter 6.

RESEARCH HYPOTHESES

With the exception of guardrail crashes, the crash types included in the analysis (see aforementioned crash filtering criteria) were chosen because the frequency of such crashes occurring at or near bridges is intuitively lower when guardrail exists on the bridge approach due to the added protection against run-off-the-road related rollover or fixed-object crashes. The frequency of guardrail crashes occurring at bridges is obviously expected to be higher for bridges with approach guardrail, but crashes with guardrail are generally less severe than most other fixed-object or rollover crashes. As a result, the researchers hypothesized that two major trends would be observed in the analyses:

1. A lower occurrence of fixed-object and other run-off-the-road crashes (except guardrail crashes) in the vicinity of the bridge for bridges with guardrail on the approach versus bridges without guardrail;
2. A lower severity of fixed-object and other run-off-the-road crashes occurring in the vicinity of bridges with guardrail on the approach versus bridges without guardrail.

Multiple analyses were performed on the crash data and are described in Chapter 4, 5, and 6 including:

- Initial investigations of crashes occurring at CSAH bridges (Chapter 4),
- Analysis of CSAH bridge-crash types based on database queries (Chapter 4),
- Analysis of CSAH bridge-crash severity based on database queries (Chapter 4),
- Analysis of the effectiveness of CSAH bridge-approach guardrail based on police crash-reports (Chapter 5), and
- Benefit/cost analysis for CSAH bridge-approach guardrail (Chapter 6).

CHAPTER 4:
ANALYSIS OF DATABASE CRASHES

INITIAL CRASH INVESTIGATIONS

Crash Frequency per Bridge

An initial analysis task was to determine the distribution of crashes per bridge. Because crashes typically occur at random, they are generally assumed to follow the Poisson distribution. However, based on the results of a chi-square test for independence, the crashes did not fit a Poisson distribution for either bridge population (p-value < 0.0001 confidence for both populations). Figure 4.1 displays the frequency of run-off-the-road and fixed-object crashes near the sample bridges from 1998-2002.

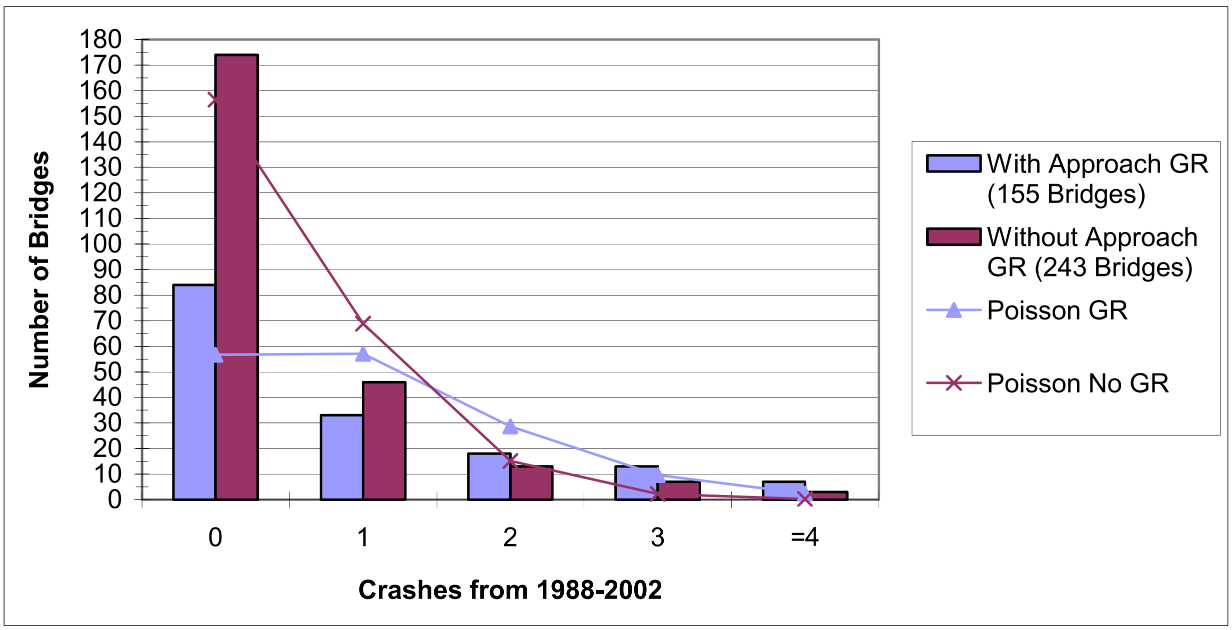


Figure 4.1. Frequency of ROR and Fixed-Object Crashes Occurring near Bridges from 1988-2002

Figure 4.1 shows that a majority of the bridges in the two samples had zero reported run-off-the-road or fixed-object crashes from 1988 – 2002. During the 15-year analysis period, the sample of 243 CSAH bridges without approach guardrail included 174 (72 percent) with zero crashes during the entire period, and 69 (28 percent) with at least one reported crash, with an average of 0.44 crashes per bridge during the entire 15-year analysis period (i.e., 0.029 crashes per bridge per year). The maximum number of crashes for any bridge without approach guardrail was six.

The percentage of bridges with at least one reported crash was considerably higher for bridges with approach guardrail. During the 15-year analysis period, the sample of 155 CSAH bridges with approach guardrail included 84 (54 percent) with zero crashes during the entire period, and 71 (46 percent) with at least one reported crash, with an average of 1.01 crashes per bridge during the entire 15-year analysis period (i.e., 0.0673 crashes per bridge per year). The higher crash frequencies for bridges with approach guardrail versus without were likely a result of higher traffic volumes. The maximum number of crashes occurring at any bridge with approach guardrail during the 15-year analysis period was ten crashes, which occurred at two locations.

Similar crash-frequency trends existed when only bridges with ADT ≤ 1,000 vpd were considered, as displayed in Figure 4.2. The percentage of bridges with zero reported crashes increased slightly regardless of guardrail presence. Additionally, the distribution of crashes that occurred at bridges with approach guardrail and ADT ≤ 1,000 vpd fit a Poisson distribution based on a chi-squared test for independence (with approach GR: p-value = 0.1287; without approach GR: p-value = 0.0020).

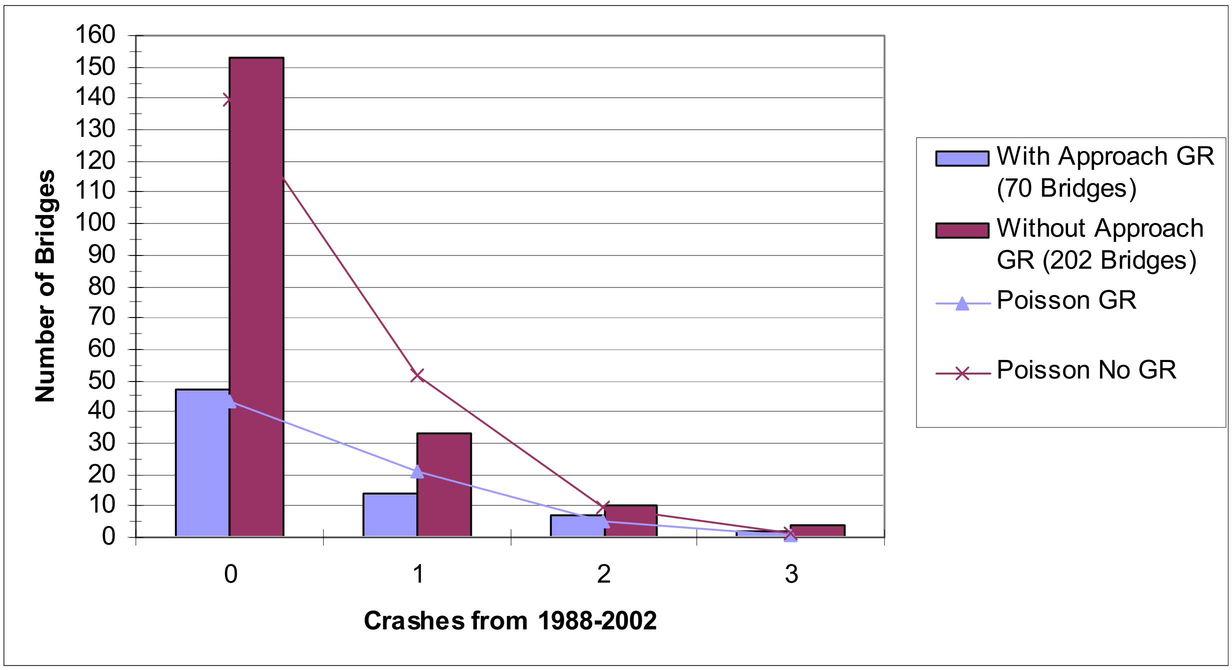
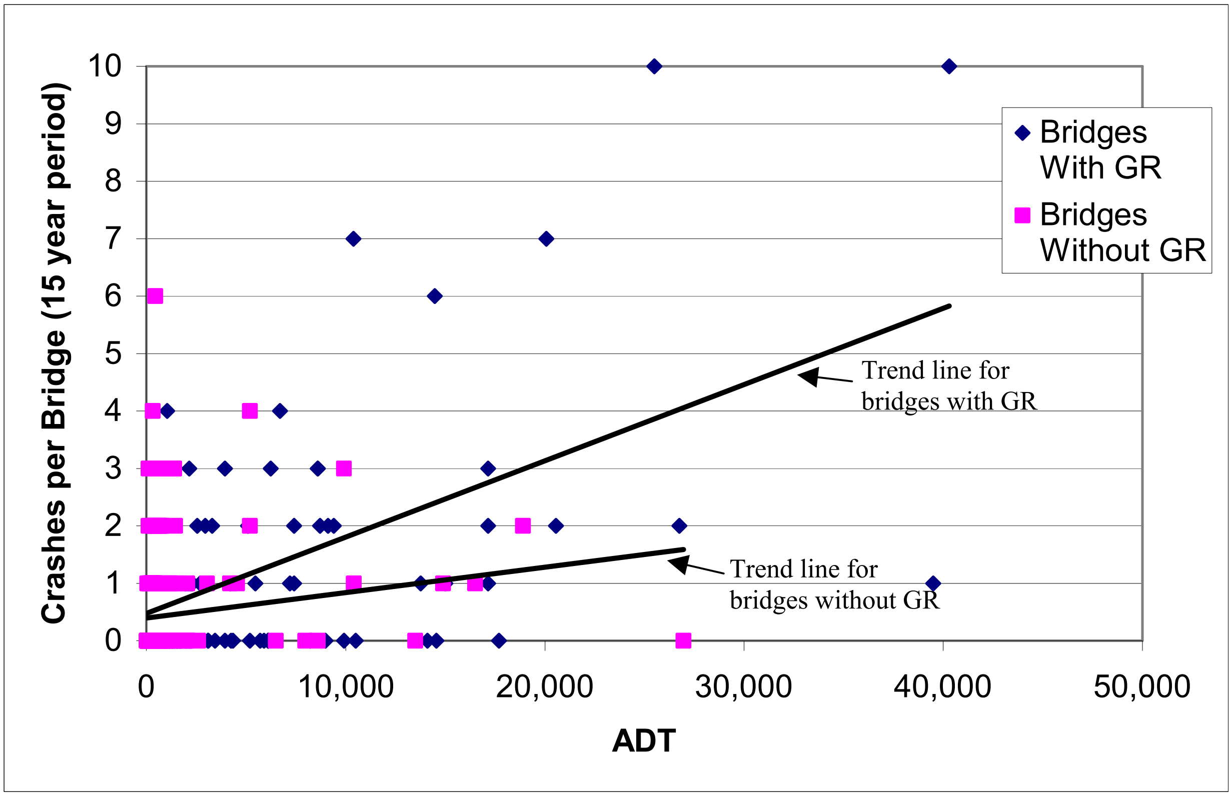


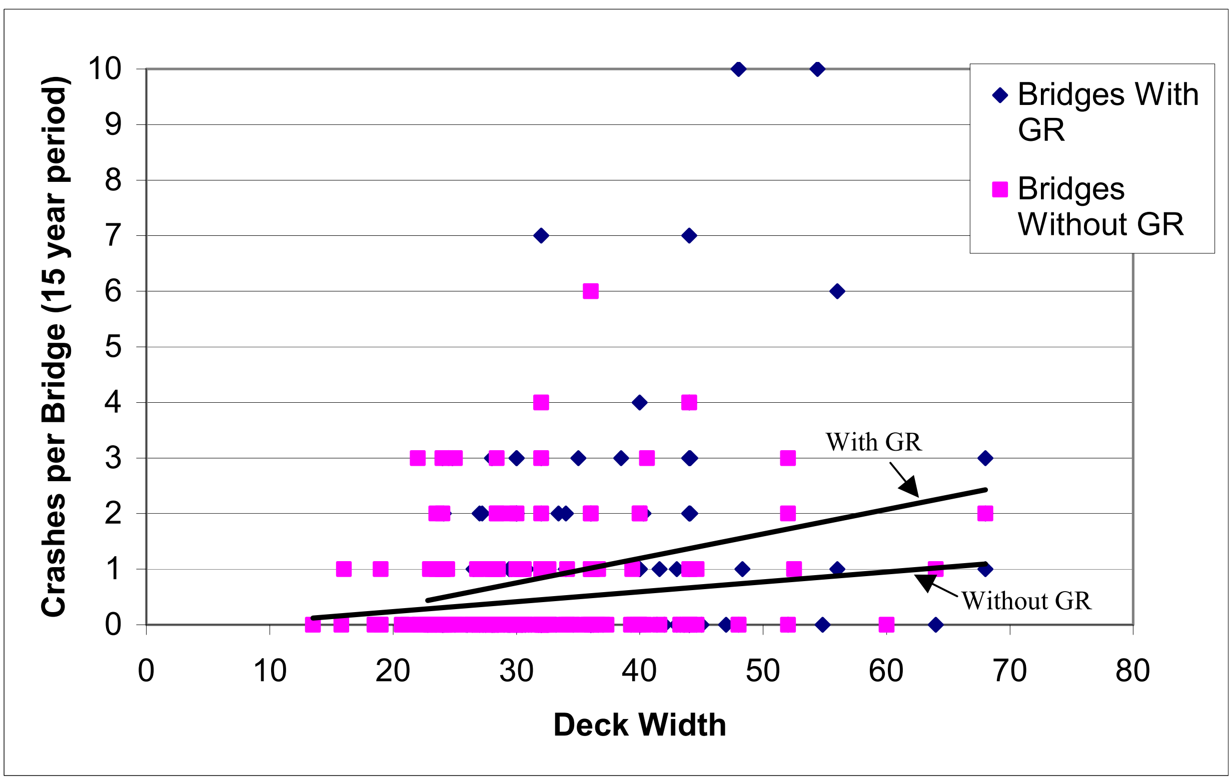
Figure 4.2. Frequency of ROR and Fixed-Object Crashes Occurring near Bridges from 1988-2002, ADT ≤ 1,000 vpd

Relationship between Crashes, ADT, and Deck Width

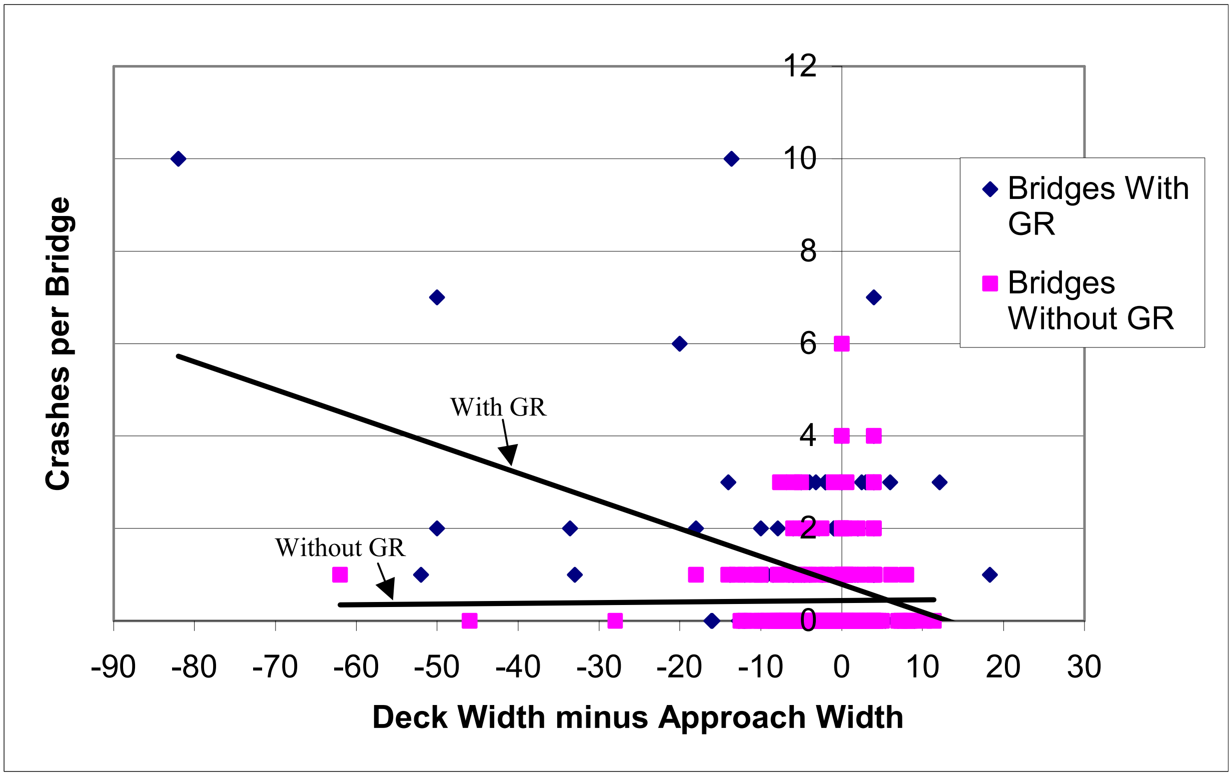
Because of the broad range of traffic volumes and deck widths for the bridges used in the analysis, it was important to determine if any trends existed between these factors and bridge-crash frequency. The researchers also considered the difference between deck width and approach roadway width since bridges that are narrower than the approaching roadway present a potential safety hazard. Figure 4.3 shows scatterplots for the run-off-the-road and fixed-object crash data for each bridge population versus the 2004 ADT on the bridge (Figure 4.3a), versus bridge deck width (Figure 4.3b), and versus deck width minus approach width (Figure 4.3c). Basic descriptive statistics are shown in Table 4.1.



a. Scatterplot of Bridge Crashes versus ADT



b. Bridge Crashes versus Deck Width



c. Bridge Crashes versus Deck Width minus Approach Width

Figure 4.3. Scatterplots of Bridge-Crash Frequency versus ADT, Deck Width, and Deck Width Minus Approach Width

Table 4.1. Descriptive Statistics for Crashes versus ADT, Deck Width, and Deck Width minus Approach Width

2004 ADT	GR	No GR
Mean	4,118	1,102
Median	1,320	325
Mode	1,351	52
Min	42	16
Max	41,524	27,785
Deck Width	GR	No GR
Mean	35.76	31.28
Median	32.1	30.1
Mode	44	32
Min	22.8	13.5
Max	68	68
Deck Width - App Width	GR	No GR
Mean	-3.61	-1.66
Median	0	0
Mode	0	0
Min	-82	-62
Max	18.3	39.4

For bridges with approach guardrail, Figure 4.3a shows a generally upward trend for crash frequency versus ADT. This trend is especially evident for ADT greater than 10,000 vpd. Figure 4.3b shows very weak linear trends between bridge crashes and deck width, regardless of approach guardrail presence/absence. Figure 4.3c shows a generally downward trend for crashes versus deck width minus approach width at bridges with approach guardrail. No considerable trends exist for crashes versus any of the three variables for bridges without approach guardrail.

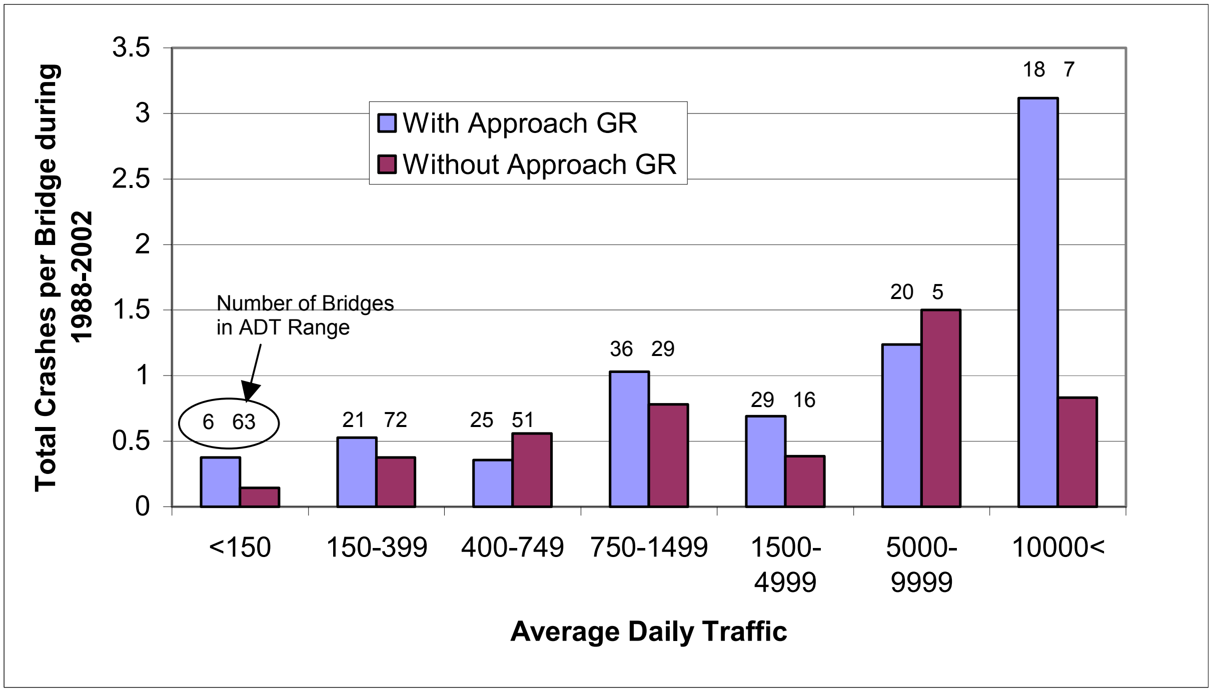
Crashes Separated by ADT

The trend lines in Figure 4.3a showed an upward linear trend between bridge crashes and ADT. In addition, Table 4.1 shows that considerable disparity exits between the average daily traffic volumes for the two bridge data sets. Thus, the bridge crashes were clustered based on ADT for further analysis. Figure 4.4 shows a comparison of the total number of run-off-the-road and fixed-object crashes per bridge occurring from 1988 - 2002 separated by ADT range. Figure 4.4a is based on all crashes in the sample, while Figure 4.4b is based only on injury/fatal crashes. Please note that the data shown in Figure 4.4 and elsewhere in this report include the sum of all crashes that occurred during the entire 15-year analysis period and are not annual rates.

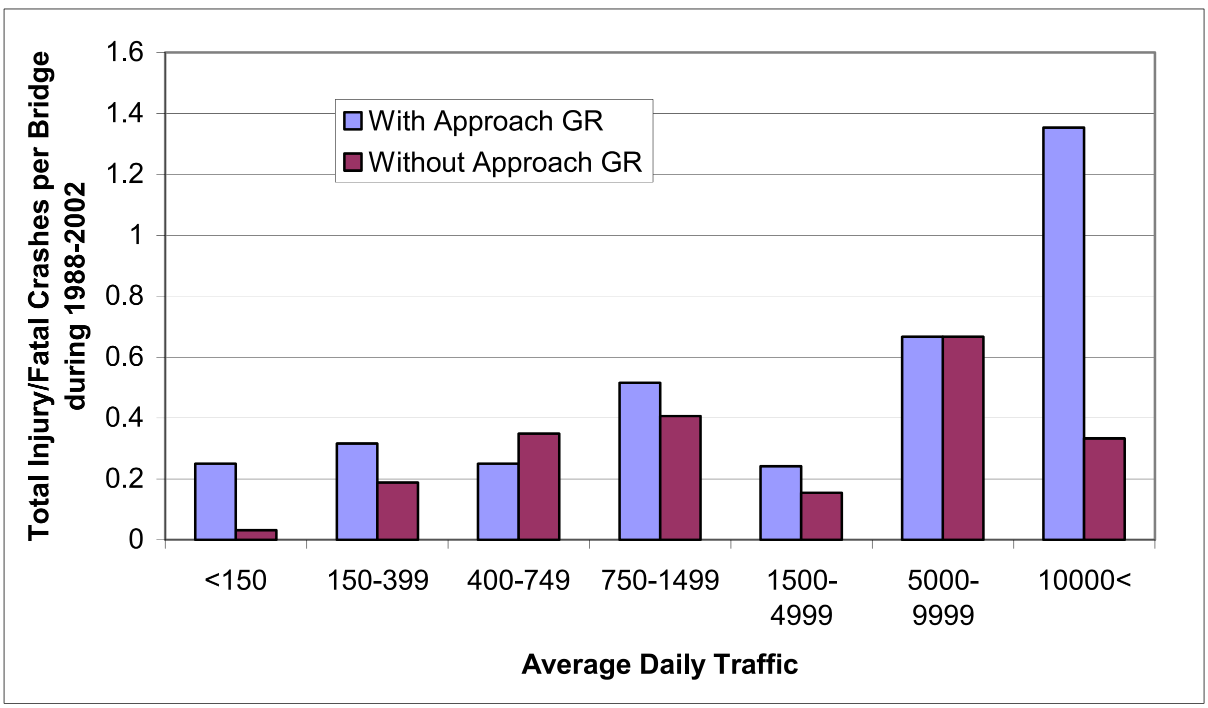
Figure 4.4 displays a number of interesting findings. The rates of crashes per bridge were similar both in magnitude and trend for bridges both with and without approach guardrail when bridges with ADT between 150 and 9,999 vpd were considered. With the exception of the 1,500 – 4,999 vpd range, there was a similar general upward trend for rate versus ADT for both bridge populations, regardless of whether or not property damage only (PDO) crashes were considered. The ADT range of 400 – 4,999 vpd contained the most balanced number of bridges with and without approach guardrail and thus should likely provide the most accurate comparison of crash rates for the two bridge populations.

Comparison of crash rates versus presence of approach guardrail for both the 150-399 and 400-749 vpd ranges was of particular significance to this study. Bridges with approach guardrail had slightly more crashes per bridge in the 150-399 vpd range, but slightly fewer crashes per bridge in the 400-749 vpd range. This trend was the same regardless of whether or not PDOs were included in the analysis.

Unusual patterns were observed for crash rates in the lowest and highest ADT ranges (i.e., ADT < 150 or ADT > 10,000) as bridges with approach guardrail had more crashes than bridges without approach guardrail. Two explanations are given for this phenomenon. First, a highly unbalanced number of bridges existed between bridges with and without approach guardrail for each of these ADT ranges. Second, for bridges in the highest ADT range, the average ADT for bridges with and without approach guardrail differed greatly with ADTs of 19,674 vpd and 16,242 vpd, respectively.



a. Run-Off-The-Road and Fixed-Object Crashes: *All Crashes*



b. Run-Off-The-Road and Fixed-Object Crashes: *Injury/Fatals Only*

Figure 4.4. Crash Frequency per Bridge versus ADT Range and Approach Guardrail Presence

ANALYSIS OF CODED CRASH TYPES

The researchers were particularly interested in whether or not the presence of approach guardrail had an effect on bridge-crash type. However, this analysis was not possible using only the crash information from the Minnesota crash database because crashes with approach guardrail and all other bridge components were coded in the crash database together as TYPE 31 "bridge piers." Thus, based on the database information, only the TYPE codes could be analyzed as described in the paragraphs that follow. A comprehensive analysis of approach guardrail effectiveness was performed using information obtained from the police crash-reports and is described in Chapter 5.

The researchers believed that the presence of guardrail on bridge approaches may redistribute the types of crashes that occur. For example, run-off-the-road fixed-object and rollover crashes are expected to be less frequent where guardrail is present. In addition, crashes with bridge components (i.e., crash TYPE 31) may actually increase when approach guardrail is present. The researchers were particularly interested in the effect that guardrail had on the frequency and severity of crashes with bridge components versus roadside fixed-object crashes and rollover crashes. To avoid "sparse" categories for the analysis (i.e., cell frequency $<$ 5), similar crash types were clustered into the three categories based on TYPE code as follows:

- Fixed-Object – Roadside (i.e, not related to the bridge), included:
    - TYPE 24 (light pole), 25 (utility pole), 26 (sign structure), 27 (mailbox), 28 (other poles), 29 (hydrant), 30 (tree/shrubbery), 35 (fence), 38 (wall), 39 (rock outcrops), 41 (other fixed-object), 42 (unknown type of fixed-object)
- Fixed-Object – Bridge, included:
    - 31 (bridge piers), 32 (median safety barrier), 33 (crash cushion), 34 (guardrail), 36 (culvert/headwall)
- Rollover/Ditch, included:
    - 37 (embankment/ditch), 51 (overturn/rollover), 52 (submersion)

The hypotheses were tested using a 2-way Pearson chi-square test for independence of the form $\chi^2 = \sum_i \sum_j \frac{(o_{ij} - e_{ij})^2}{e_{ij}}$, where o_{ij} = observed frequency and e_{ij} = expected frequency for cell ij. The probability of e_{ij} is computed by multiplying the row total count by column total count divided by the overall total count for the table. The Pearson chi-square test measures the independence (or level of association) between the rows and columns in the table; for example, testing the null hypothesis (H_o) that bridge-crash type does not depend on the presence/absence of approach guardrail. The degrees of freedom for a 2-way Pearson chi-square test = (# rows - 1)*(# columns -1). All statistical testing was performed at a 95 percent level of confidence. In other words, a p-value of less than 0.05 indicates a statistically significant difference between the row-by-row distribution of crashes for bridges with approach guardrail versus those without.

All Bridges

The researchers first analyzed database crashes from all 398 bridges to determine if the presence of approach guardrail had an effect on the types of run-off-the-road crashes occurring at bridges. Table 4.2 and Figure 4.5 present the results of the chi-square analysis for database crashes occurring at the 398 bridges during the 15-year analysis period.

Table 4.2. Chi-Square Test for Crash Type versus Guardrail Presence, All Bridges

Crash Type Cluster	Percent No GR	GR	Total	Total Count
Fixed Obj. - Roadside	13.5	24.3	20.2	50
Fixed Obj. - Bridge	45.8	44.7	45.1	112
Rollover/Ditch	40.6	30.9	34.7	86
Total Percent	100.0	100.0	100.0	248
Total Count	96	152	248	
Test statistic	Value	df	Prob	Statistically Significant Differences?
Pearson chi-square	5.018	2	0.081	**No**

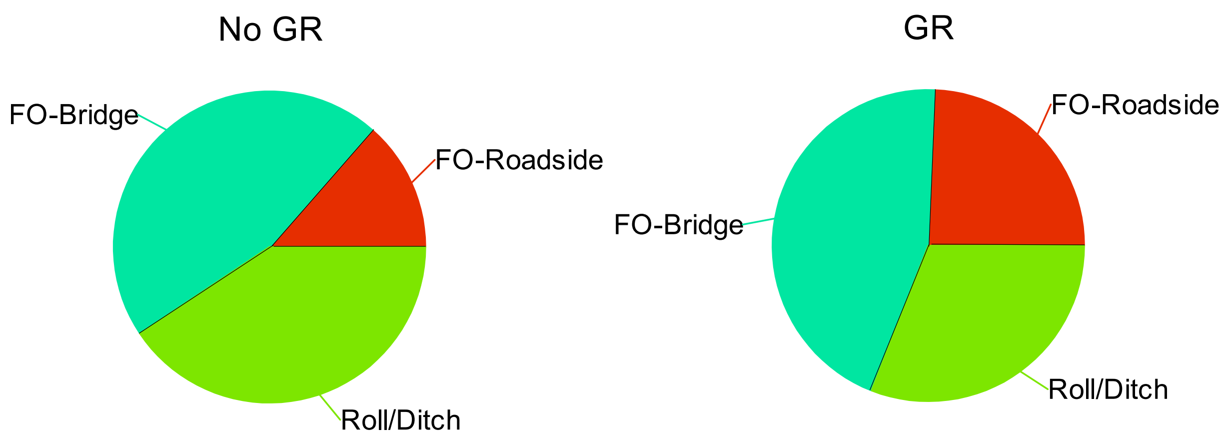


Figure 4.5. Crash Type versus Guardrail Presence, All Bridges

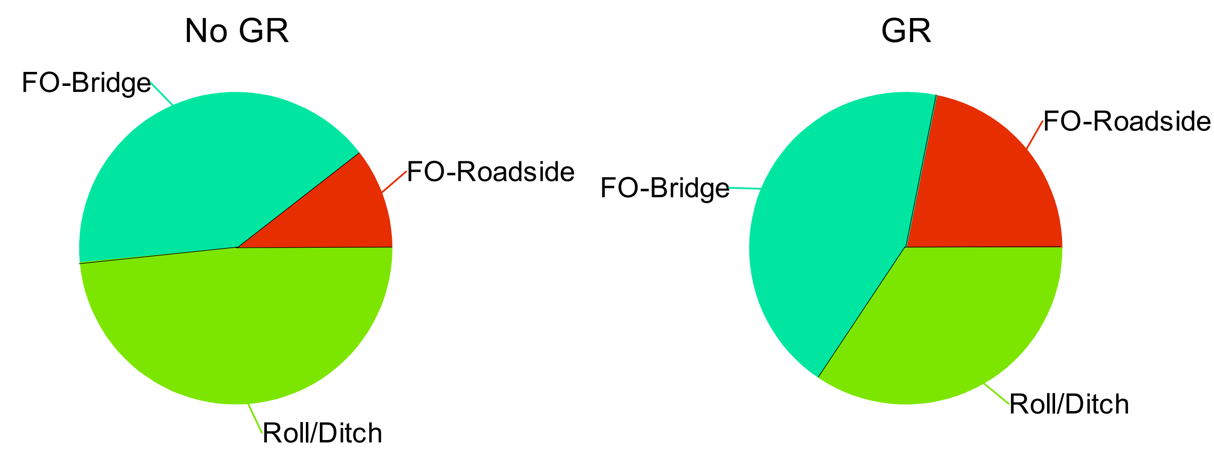
Both Table 4.2 and Figure 4.5 show slight, although non-statistically significant, differences in the proportion of crash types that occur at the bridges – particularly fixed-object roadside and rollover/ditch crashes. Rollover/ditch crashes are slightly more frequent for bridges without guardrail than bridges with guardrail, which was expected. Crashes with non-bridge-related fixed-objects on the roadside were more frequent for bridges with approach guardrail than those without, which was not expected. However, none of these differences were statistically significant and thus could not be attributed to the presence or absence of approach guardrail.

Data Separated by ADT

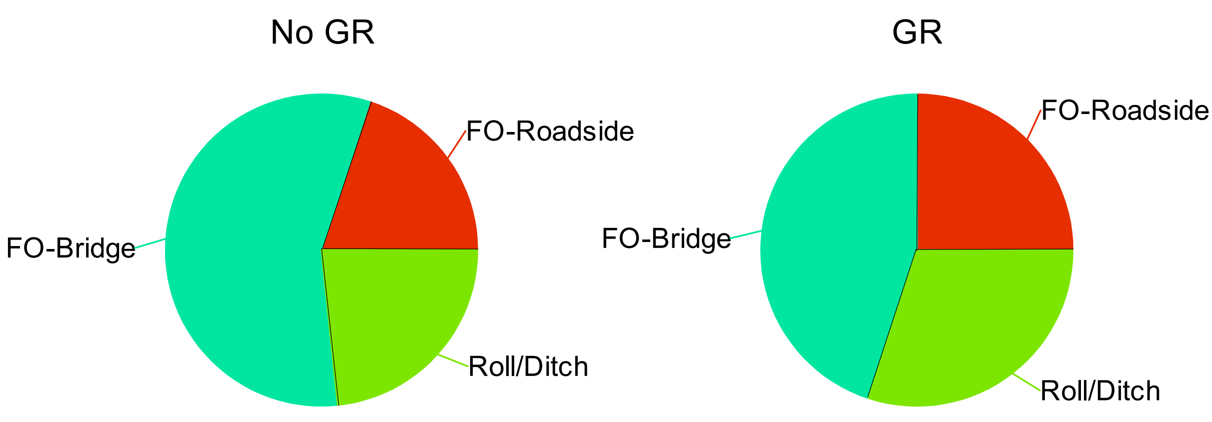
Because crash frequency may be influenced by traffic volume, the researchers deemed it appropriate to perform the analysis with data separated into similar ADT categories. To avoid the problems associated with sparse categories, data were split into only two ADT classes: ADT ≤ 1,000 vpd and ADT > 1,000 vpd. The results of the analysis are found in Table 4.3 and Figure 4.6 that follow.

Table 4.3. Chi-Square Test for Crash Type versus Guardrail Presence Separated by ADT

	Crash Type Cluster	No GR (pct.)	GR (pct.)	Total (pct.)	Total Count
ADT ≤ 1,000	Fixed Obj. - Roadside	10.6	21.8	14.2	14
	Fixed Obj. - Bridge	40.9	43.7	41.8	41
	Rollover/Ditch	48.4	34.3	43.8	43
	Total Percent	100.0	100.0	100.0	
	Total Count	66	32	98	
	Test statistic	Value	Df	Prob	Statistically Significant Differences?
	Pearson chi-square	2.935	2.000	0.230	**No**
ADT >1,000	Crash Type Cluster	No GR (pct.)	GR (pct.)	Total (pct.)	Total Count
	Fixed Obj. - Roadside	20.0	25.0	24.0	36
	Fixed Obj. - Bridge	56.6	45.0	47.3	71
	Rollover/Ditch	23.3	30.0	28.6	43
	Total Percent	100.0	100.0	100.0	
	Total Count	30	120	150	
	Test statistic	Value	df	Prob	Statistically Significant Differences?
	Pearson chi-square	1.312	2.000	0.519	**No**



a. ADT ≤ 1,000



b. ADT > 1,000

Figure 4.6. Crash Type versus Guardrail Presence and ADT Category

Based on Table 4.3 and Figures 4.6a-b, it does not appear that separation of database crashes into ADT category has any improved effect on the analysis as no statistically significant differences were found between the crash types for bridges with approach guardrail versus those without.

ANALYSIS OF CRASH SEVERITY

The researchers were also interested in whether or not the presence of approach guardrail had an effect on CSAH bridge-crash severity. Guardrail is not intended to reduce the frequency of crashes, although it is designed to reduce the severity of crashes when they occur. Because of this the researchers hypothesized that presence of approach guardrail at bridges would result in a lower crash severity. In other words, guardrail was expected to be associated with a lesser proportion of severe injury/fatal crashes (i.e., K, A, B, and C crash severities using KABCO scale) and greater proportion of property damage (PDO) crashes.

A Pearson chi-square analysis of the crash severity for bridges with approach guardrail versus those without was performed on the database crashes. Again, all statistical testing performed at a 95 percent level of confidence. A more comprehensive severity analysis was performed using information obtained from the police crash-reports and is described in Chapter 5.

All Bridges

The researchers first analyzed data from all 398 bridges to determine if the presence of approach guardrail had an effect on the crash severity. Table 4.4 and Figure 4.7 present the results of the chi-square analysis for crashes occurring at the 398 bridges during the 15-year analysis period.

Table 4.4. Chi-Square Test for Crash Severity versus Guardrail Presence, All Bridges

Crash Severity	Percent No GR	GR	Total	Total Count
A (incapacitating injury)	10.2	7.6	8.7	23
B (non-incapacitating injury)	18.6	23.7	21.6	57
C (possible injury)	14.9	16.6	15.9	42
K (fatal)	5.6	0.6	2.6	7
PDO (no injury)	50.4	51.2	50.9	134
Total Percent	100.0	100.0	100.0	
Total Count	107	156	263	
Test statistic	Value	df	Prob	Statistically Significant Differences?
Pearson chi-square	7.233	4.000	0.124	**No**

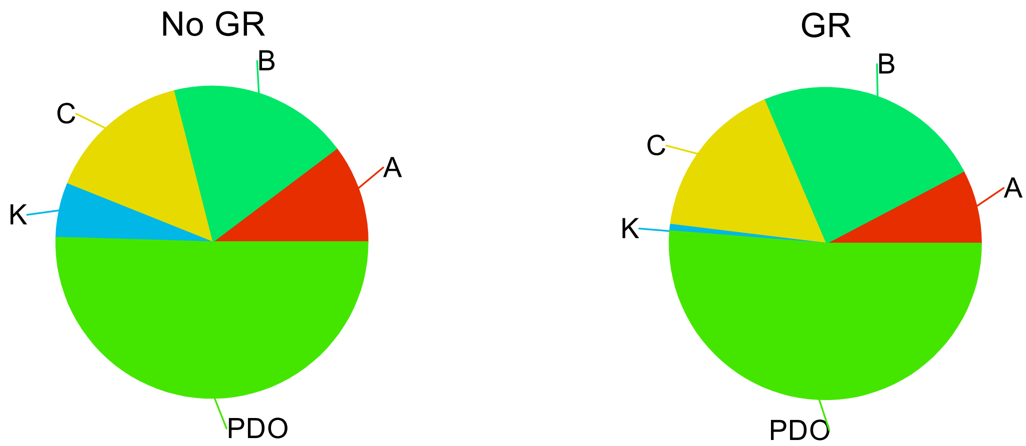


Figure 4.7. Crash Severity (KABCO scale) versus Guardrail Presence, All Bridges

Both Table 4.4 and Figure 4.7 show only slight non-statistically significant differences in the proportion of crash types that occur versus presence of approach guardrail. It is important to note that only one of the 156 crashes (0.6 percent) at bridges with approach guardrail was a fatality compared to six of the 107 crashes (5.6 percent) at bridges without approach guardrail. This finding will be discussed in greater detail in the analysis of police crash-reports described in Part 4 of this chapter.

Data Separated by ADT

Again, because crash frequency is influenced by traffic volumes, the researchers deemed it appropriate to perform the severity analysis with data separated into similar ADT categories. To avoid a high number of sparse categories, (i.e., cell frequency < 5) injury/fatal crashes were pooled together (i.e., K, A, B, and C crash severities) and analyzed versus PDO crashes. To further address problems associated with sparse categories, data were split into only two ADT classes: ADT ≤ 1,000 vpd and ADT > 1,000 vpd. The results of the analysis are found in Table 4.5 and Figure 4.8.

Table 4.5. Chi-Square Test for Crash Severity versus Guardrail Presence Separated by ADT

	Crash Severity	No GR (pct.)	GR (pct.)	Total (pct.)	Total Count
	A (incapacitating injury)	13.3	14.7	13.7	15
	B (non-incapacitating injury)	21.3	17.6	20.1	22
	C (possible injury)	12.0	26.4	16.5	18
	K (fatal)	5.3	0.0	3.6	4
ADT ≤ 1,000	PDO (no injury)	48.0	41.1	45.8	50
	Total Percent	100.0	100.0	100.0	
	Total Count	75	34	109	
	Test statistic	Value	df	Prob	Statistically Significant Differences?
	Pearson chi-square	5.207	4.000	0.267	**No**
	Crash Severity	No GR (pct.)	GR (pct.)	Total (pct.)	Total Count
	A (incapacitating injury)	3.1	5.7	5.1	8
	B (non-incapacitating injury)	12.5	25.4	22.7	35
	C (possible injury)	21.8	13.9	15.5	24
	K (fatal)	6.2	0.8	1.9	3
ADT >1,000	PDO (no injury)	56.2	54.0	54.5	84
	Total Percent	100.0	100.0	100.0	
	Total Count	32	122	154	
	Test statistic	Value	df	Prob	Statistically Significant Differences?
	Pearson chi-square	7.077	4.000	0.132	**No**

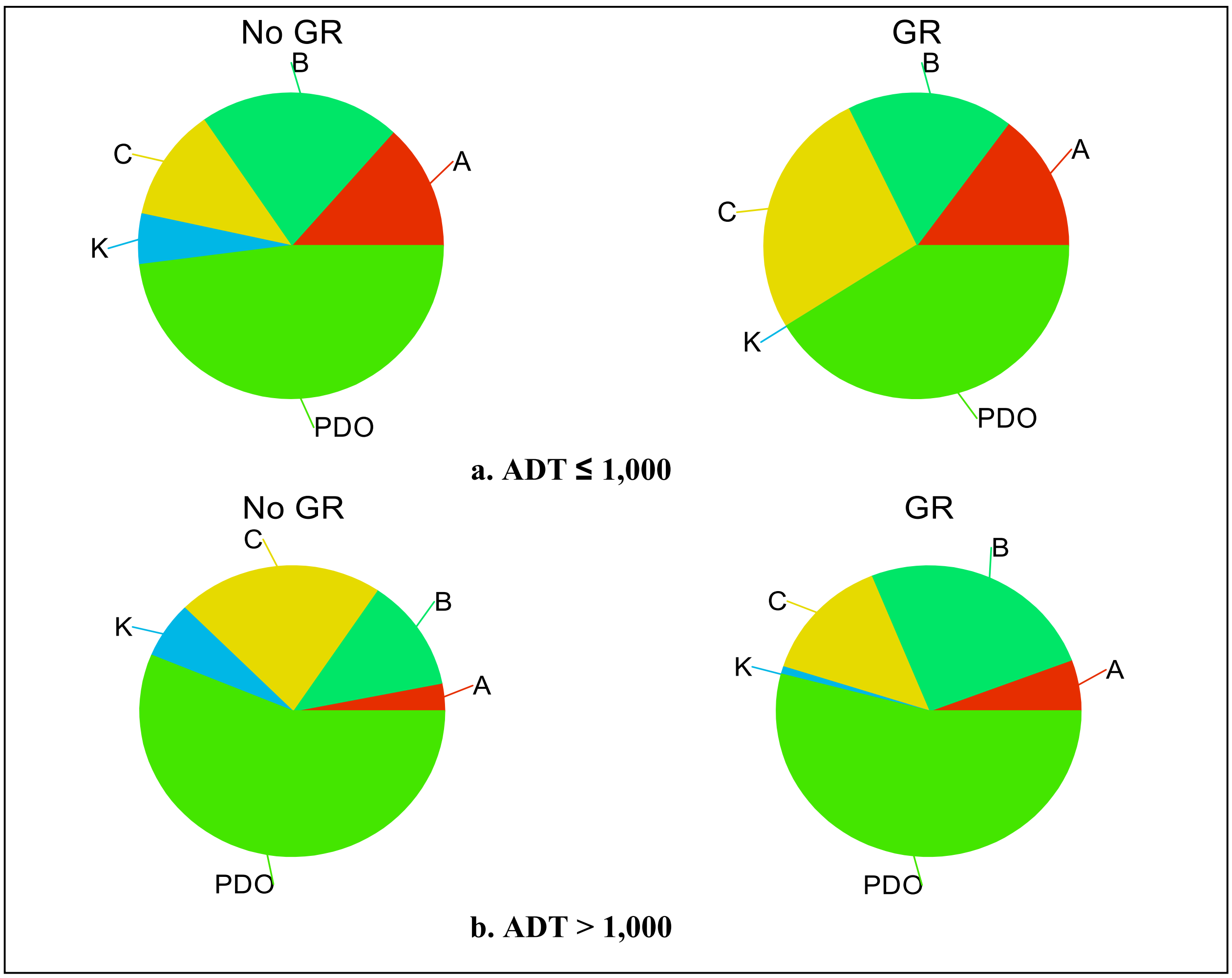


Figure 4.8. Crash Severity versus Guardrail Presence and ADT Category

Based on Table 4.5 and Figure 4.8, it does not appear that separation of crashes into ADT category has any improved effect on the analysis. Similar to the analysis of all data, fatalities were considerably lower for bridges with approach guardrail versus those without in both ADT categories.

CHAPTER 5:
ANALYSIS OF POLICE CRASH-REPORT DATA

The major objective of the research described herein was to determine if the presence of approach guardrail had an effect on both the type and severity of crashes occurring near the respective bridges. In particular, the researchers hypothesized that for crashes occurring near bridges, the presence of approach guardrail would result in:

- A greater proportion of guardrail crashes;
- A lower proportion of other types of fixed-object crashes (i.e., bridge rail, trees, ditches) and rollover crashes; and
- A lower proportion of severe crashes (i.e., fatal and A-injury).

Collisions with approach guardrail and all other bridge components were combined into a single database code: TYPE 31 "bridge piers". As a result, the effectiveness of approach guardrail could not be specifically determined using solely the crash database information. Furthermore, the researchers wanted to focus solely on the crashes that could be directly related to the presence or absence of approach guardrail. Therefore, a detailed microscopic review of the respective police crash-reports was required.

CRASH REPORT ACQUISITION

Hard copies of specific police crash-reports were requested from Mn/DOT. Although a time consuming task, analyzing the diagrams and descriptions contained within each police crash-report provided detailed information that was not available from the Mn/DOT crash database. Researchers also had several questions pertaining to the crash coding methods for certain fixed-object collisions, namely the predominant types of objects struck for TYPE 31 "bridge pier" crashes.

A police report was requested for all crashes meeting one or more of the following criteria:

- Crashes with a bridge or safety component:
    - Crash TYPE = 31 (bridge pier), 32 (median barrier), 33 (crash cushion), 34 (guardrail), 36 (culvert);
- Crashes with a roadside fixed-object or rollover:
    - Crash TYPE = 25 (utility pole), 26 (sign structure), 30 (tree/shrubbery), 37 (embankment/ditch/ culvert), 41 (other fixed-object), 51 (rollover), or 90 (other type of crash); or
- Injury TYPE = K or A.

238 of the 263 total run-off-the-road and fixed-object crashes met the above requirement and were thus requested from Mn/DOT.

REPORT SCREENING AND FILTERING

After receiving the hard copies of the 238 crash reports, researchers analyzed each of the diagrams and crash descriptions to obtain the following information:

- Did the crash involve a bridge component (including approach guardrail) or did a run-off-the-road crash occur very near the bridge, potentially prevented by approach- or departure-side guardrail connected to the bridge?
- Did the crash occur on the approach side of the bridge, departure side, or on the bridge itself?
- If approach (or departure) guardrail did not exist, would approach (or departure) guardrail have improved the situation either through redirection of the vehicle back onto the roadway or attenuation of the vehicle with the end of the bridge rail?
- If approach (or departure) guardrail did exist, was it effective at preventing a potentially more severe crash?
- Did the coded crash type fit the police officer's description?

After each report was reviewed, the researchers assessed whether or not it was appropriate for inclusion in any of the desired analyses based on the following criteria:

- The crash occurred on the approach or departure and within approximately 200 feet of the appropriate CSAH bridge and
- The crash involved collision with a bridge component, roadside fixed-object, or other roadside collision.

Screening Results

Of the 238 reports that were screened, ten were unusable for a variety of reasons, such as: illegible report, no diagram or description on file, and/or lack of relevant information. Of the 228 usable reports now available, 100 were determined not to be related to the objectives of this analysis in that they were most likely unrelated to the presence/absence of approach guardrail. Many of these crashes were run-off-the-road crashes occurring within the designated bridge 'zone' as described in the crash database analysis but outside the reach of the typical guardrail application. Another 26 crashes were removed from the analysis because they occurred entirely while the vehicle was on bridge and were thus unaffected by the presence/absence of approach guardrail. Most of these 26 crashes were PDO involving a sideswipe with the bridge rail. Finally, six reports involved motorcycles and were also excluded from the analysis. Thus, 96 of the initial 238 crash reports were used in the final analyses.

Of the 96 analyzed crash reports, 47 involved crashes occurring at 32 bridges with approach guardrail, while the remaining 49 crashes occurred at 36 bridges without approach guardrail. Table 5.1 displays the frequency of target crashes at the sample CSAH bridges.

Table 5.1. Crash Frequency at CSAH Bridges

Crashes Observed per Bridge	Number of Bridges		
	No GR	GR	Total
1	27	23	50
2	5	7	12
3	4	1	5
7	0	1	1
Total Bridges	36	32	68
Total Crashes	49	47	96

The specific detail provided in the police report sketches and narratives allowed for a detailed microscopic analysis of crashes that were very likely affected by approach guardrail or the lack thereof. Thus, detailed analyses of the safety effectiveness of approach guardrail could be performed. The results of the safety analyses were later used to determine the financial savings provided by approach guardrail at various levels of traffic.

ANALYSES AND RESULTS

Numerous analyses were performed to satisfy the research objectives, including:

- Initial object struck:
  - Chi-square analysis for object struck versus guardrail presence,
  - Chi-square analysis for object struck versus guardrail presence for TYPE 31 crashes only,
- Crash severity:
  - Logistic regression analysis for crash severity versus object struck, surface condition, 2004 ADT, speed limit, deck width, and deck width minus approach width,
  - Chi-square analysis for crash severity versus guardrail presence,
  - Chi-square analysis for crash severity versus object struck,
- Guardrail effectiveness and placement:
  - Chi-square analysis for effectiveness of guardrail based on type of collision and guardrail presence, and
  - Assessment of the need for departure-side guardrail in addition to approach-side guardrail.

The following sections detail the analyses and their results.

Initial Object Struck versus Guardrail Presence

The initial analysis focused on whether or not the presence of approach guardrail had an effect on the initial object struck. The researchers hypothesized that presence of approach guardrail would result in a greater occurrence of guardrail crashes and a lesser occurrence of crashes with all other types of bridge components, roadside fixed-objects, and rollover crashes when compared to bridges without approach guardrail.

Table 5.2 displays a breakdown of the crash types for the 96 crashes as coded in the Minnesota database. The summarized list of attributes from the 96 crash reports, including police descriptions and diagram summaries, can be found in Appendix F.

Table 5.2. Coded Crash Types versus Guardrail Presence

Crash Type	No GR	GR	Total
25 “utility pole”	0	1	1
26 “sign structure/post”	1	1	2
30 “tree/shrubbery”	4	1	5
31 “bridge piers”	33	34	67
33 “crash cushion”	0	1	1
34 “guardrail”	1	2	3
35 “fence”	0	1	1
37 “embankment”	2	1	3
41 “other fixed-object”	1	0	1
51 “overturn/rollover”	7	5	12
Total	49	47	96

Table 5.2 shows 67 of the 96 crashes (69 percent) occurring near the bridges were coded in the database as TYPE 31 “bridge piers,” while very few crashes were coded TYPE 34 “guardrail”. Discussions with Mn/DOT staff indicated that for crashes included in this study, database TYPE 31 “bridge piers” represented crashes with any component of the bridge, including approach guardrail. TYPE 34 represented crashes with other guardrail not connected to a bridge. Thus, the Minnesota crash-reporting system does not include a specific code for either bridge rail or approach guardrail; rather both were included in TYPE 31 making it impossible to make inferences on the effectiveness of guardrail based solely on analysis of database crash records. A breakdown of the initial object struck for crashes coded as TYPE 31 can be found in the next section of this report. A more detailed explanation of the Minnesota coding procedures for crash TYPE exists in Appendix G.

The researchers used the diagrams and descriptions from the crash report to determine the initial object struck (or first harmful event, in the case of roadside crashes) for each of the crashes. Because of the uncontrolled variation in the roadside conditions from bridge to bridge, all roadside crashes not involving a bridge component were clustered together in a single category. The hypotheses were tested using a Pearson two-way chi-square test for independence at a 95 percent level of confidence. Table 5.3 and Figure 5.1 display the results of the chi-square analysis.

Table 5.3. Chi-Square Test for Initial Object Struck versus Guardrail Presence

Initial Object Struck	Percent No GR	GR	Total	Total Count
Bridge Rail (BR)	71.4	6.4	39.6	38
Guardrail (GR)	0.0	51.1	25.0	24
BR/GR Connection	0.0	19.1	9.4	9
Roadside	28.6	23.4	26.0	25
Total Percent	100.0	100.0	100.0	96
Total Count	49	47	96	
Test statistic	Value	df	Prob	Statistically Significant Differences?
Pearson chi-square	60.292	3.000	0.000	**Yes**

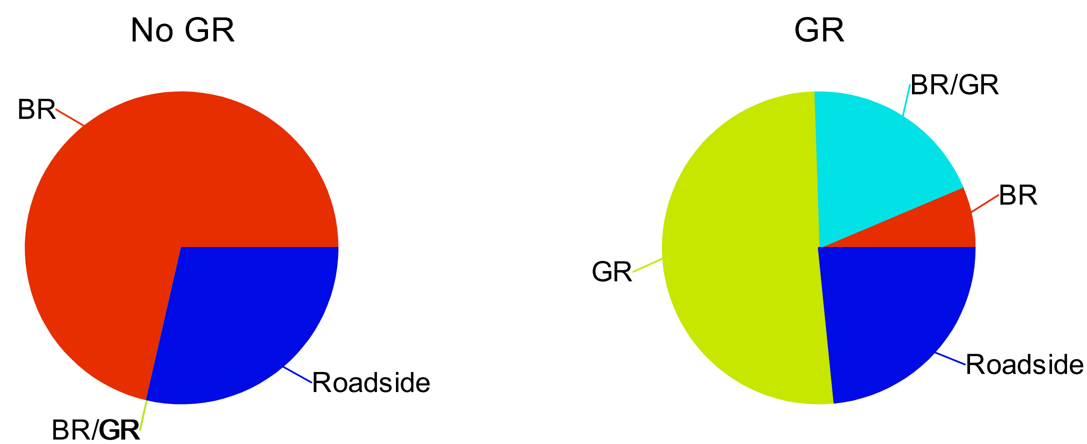


Figure 5.1. Initial Object Struck versus Guardrail Presence

Table 5.3 and Figure 5.1 show that approximately 71 percent of the crashes occurring near bridges without approach guardrail were collisions with the bridge rail, while approximately 29 percent were collisions with a roadside fixed-object or rollover. As expected, the results were much different for bridges with approach guardrail. Seventy percent of the crashes near bridges with approach guardrail involved collision with either the guardrail or the bridge rail/guardrail connection, while only six percent were collisions with the bridge rail. Roadside collisions comprised 23 percent of the crashes for bridges with guardrail.

Initial Object Struck versus Guardrail Presence for Crashes Coded as TYPE 31

As previously stated, the Minnesota crash reporting system does not included a specific code for either bridge rail or approach guardrail, rather both were typically coded as TYPE 31 “bridge piers,” which represented crashes with any component of the bridge, including approach guardrail. A detailed review of the police diagrams/descriptions showed all of the 67 analyzed crashes coded in the database as TYPE 31 “bridge piers” were bridge rail and approach guardrail crashes. Table 5.4 and Figure 5.2 display a breakdown of the initial objects struck for the 67 crashes coded with TYPE = 31.

Table 5.4. Initial Object Struck for Crashes Coded as TYPE 31

Initial Object Struck	Percent No GR	GR	Total	Total Count
Bridge Rail (BR)	100.0	17.6	58.2	39
Guardrail (GR)	0.0	58.8	29.8	20
BR/GR Connection	0.0	23.6	12.0	8
Total Percent	100.0	100.0	100.0	67
Total Count	33	34	67	

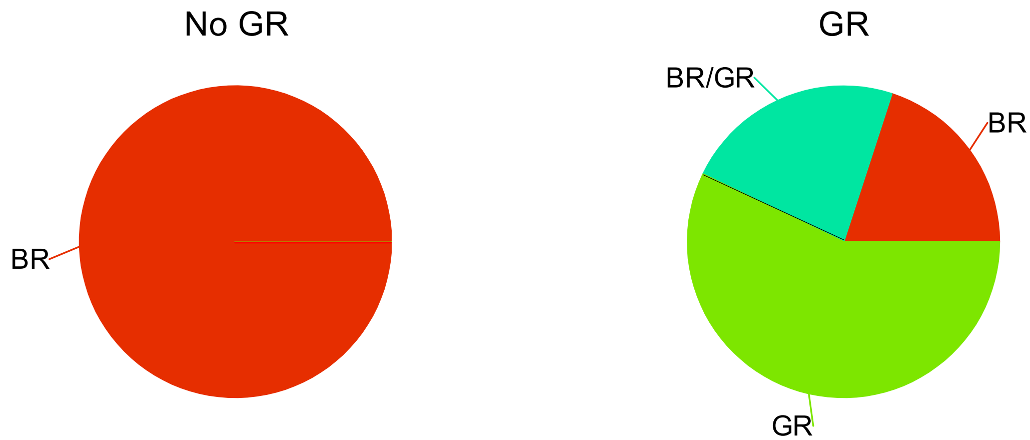


Figure 5.2. Initial Object Struck for Crashes Coded as TYPE 31

Many interesting findings are displayed in Table 5.4 and Figure 5.2. All of the TYPE 31 collisions for bridges without approach guardrail were collisions with the bridge rail. However, for bridges with approach guardrail, the primary fixed-objects struck included: guardrail (59 percent), bridge rail (18 percent), and the bridge rail/guardrail connection (23 percent). Interestingly, none of the 67 crashes coded as TYPE 31 were actually pier (i.e., supporting column) strikes. This is not surprising since a pier strike on a typical CSAH bridge over water is virtually impossible, since it would require a vehicle to run-off-the-road and travel back under the bridge in order to strike a pier column. Thus, using the description of "bridge pier" for TYPE 31 is a misnomer, at least for bridges over water.

Logistic Regression Analysis for Crash Severity versus Various Bridge and Crash Factors

Logistic regression modeling was used to predict crash severity as a function of various bridge and crash factors for the sample of 96 crashes. Logistic regression is useful for predicting the probability of an outcome based on values of a set of predictor variables. Specifically, ordinal logistic regression was used here because the response for the dependent variable (severity) is ordered, but the distances are non-numeric (i.e., A-injury is more severe than B-injury). The ordinal logistic regression model for binary response has the form:

$$\ln\left[\frac{p_i}{(1-p_i)}\right] = \alpha + \beta' X_i \quad (1)$$

Where: p_i = Probability$(y_i = y_1 \mid X_i)$ is the response probability to be modeled (i.e., crash severity given that a crash has occurred), and y_1 is the first ordered level of y

α = Intercept parameter

β' = Vector of slope parameters

X_i = Vector of predictor variables

A stepwise ordinal logistic regression model was developed for crash severity versus object struck, surface condition, 2004 ADT, speed limit, deck width, and deck width minus approach width. These predictor variables were chosen because they are often associated with crash severity. The alpha for a predictor to be entered into the stepwise model was 0.10. The analysis was run in SAS using the LOGISTIC procedure. The results are displayed in Table 5.5 with discussion to follow.

Table 5.5. Results of Ordinal Logistic Regression Analysis for Crash Severity

Summary of Stepwise Selection

Step	Entered	DF	No. In	Score Chi-Square	Pr > Chi-square
1	OBJECT	2	1	7.8278	0.0200

No additional predictors met the 0.1 significance level necessary for entry into the model.
Predictors not entered: SURFACE COND., ADT, SPEED LIMIT, DECK WIDTH, DECK WIDTH - APP. WIDTH

Score Test for the Proportional Odds Assumption

Chi-Square	DF	Pr > Chi-square
5.3263	2	0.0697

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Std. Error	Chi-Square	Pr > Chi-square	
Intercept (K/A)	1	-2.3331	0.4229	30.4366	<.0001	Sig.
Intercept (K/A + B/C)	1	-0.3460	0.3470	0.9942	0.3187	Insig.
OBJECT Roadside	1	1.0233	0.5134	3.9719	0.0463	Sig.
OBJECT Bridge Rail	1	1.1973	0.4674	6.5610	0.0104	Sig.

Odds Ratio Estimates

Effect	Point Estimate	95% Confidence Limits	
OBJECT Roadside vs Guardrail	2.782	1.017	7.611
OBJECT Bridge Rail vs Guardrail	3.311	1.325	8.276

The stepwise logistic regression analysis showed object struck (OBJECT) to be the only predictor variable with a significant effect on the response variable, crash severity. Interpretation of the score test verifies that the proportional odds model is adequately valid for fitting the data (p-value = 0.0697). Thus, the odds-ratio estimates could then be used to determine the probability of a certain crash severity based on the object struck in the collision. Because the ordinal logistic regression equation is a binary function, two equations were necessary to represent the three severity levels (K or A-injury, B- or C-injury, PDO):

$$\ln\left[\frac{\pi_{K/A}}{(\pi_{B/C}+\pi_{PDO})}\right] = -2.3331 + 1.0233x_{roadside} + 1.1973x_{bridgerail} \quad (2)$$

$$\ln\left[\frac{(\pi_{K/A}+\pi_{B/C})}{\pi_{PDO}}\right] = -0.3460 + 1.0233x_{roadside} + 1.1973x_{bridgerail} \quad (3)$$

Where: $\pi_{K/A}$ = Probability of Fatal or A-injury
$\pi_{B/C}$ = Probability of B- or C-injury
π_{PDO} = Probability of Property Damage Only
$x_{roadside}$ = Roadside crash indicator (1 if yes, 0 otherwise)
$x_{bridgerail}$ = Bridge rail crash indicator (1 if yes, 0 otherwise)
Note: Guardrail crash is indicated by 0's for both $x_{roadside}$ and $x_{bridgerail}$

Accordingly, based on the preceding equations, the predicted probabilities for each crash severity versus object struck can be calculated in the following way:

$$\pi_{K/A} = \frac{e^{equation(2)}}{1+e^{equation(2)}} \quad (4)$$

$$\pi_{B/C} = \frac{e^{equation(3)}}{1+e^{equation(3)}} - \frac{e^{equation(2)}}{1+e^{equation(2)}},\ (\pi_{K/A}+\pi_{B/C} = \frac{e^{equation(3)}}{1+e^{equation(3)}}) \quad (5)$$

$$\pi_{PDO} = 1-(\pi_{K/A}+\pi_{B/C}) \quad (6)$$

Using equations 4, 5, and 6, the probabilities of a crash being of K/A, B/C, and PDO severity level can be calculated for collisions with the roadside, bridge rail, and guardrail as shown in Table 5.6.

Table 5.6. Probabilities of Crash Severity versus Object Struck Based on Logistic Regression

	Probability		
Severity	Roadside	Bridge Rail	Guardrail
PDO	0.337	0.299	0.586
B/C	0.451	0.458	0.326
K/A	0.213	0.243	0.088

Table 5.6 shows that fatal and A-injuries are approximately 2.5 more likely to result if the collision occurs with the roadside or bridge rail versus guardrail. Guardrail collisions are roughly twice as likely to result in no injuries versus roadside or bridge rail collisions. The most severe collisions are those with the bridge rail, although roadside collisions are nearly as severe.

Crash Severity versus Guardrail Presence

Also of interest was whether or not the presence of approach guardrail had an effect on crash severity. Although guardrail is not intended to reduce the frequency of crashes, it is designed to reduce the severity of crashes when they occur. Because of this, the researchers hypothesized that presence of approach guardrail at bridges would result in a lower crash severity. In other words, guardrail was expected to be associated with a lesser proportion of severe injury/fatal crashes (i.e., K and A crash severities) and greater proportion of property damage (PDO) crashes. The hypothesis was tested using a two-way Pearson chi-square test for independence, performed at a 95 percent level of confidence. To avoid sparse categories in the chi-squared test, crashes were clustered into three severity categories: PDO, B/C, and K/A. Table 5.7 and Figure 5.3 show the clustered KABCO severity rates and associated chi-squared analysis.

Table 5.7. Chi-Square Test for Crash Severity versus Guardrail Presence

Crash Severity	Percent No GR	GR	Total	Total Count
PDO (no injury)	36.7	46.8	41.7	40
B/C (non-incapacitating injury or possible injury)	34.7	46.8	40.6	39
K/A (fatal or incapacitating injury)	28.6	6.4	17.7	17
Total	100.0	100.0	100.0	
N	49	47	96	
Test statistic	Value	df	Prob	Statistically Significant Differences?
Pearson chi-square	8.121	2.000	0.017	**Yes**

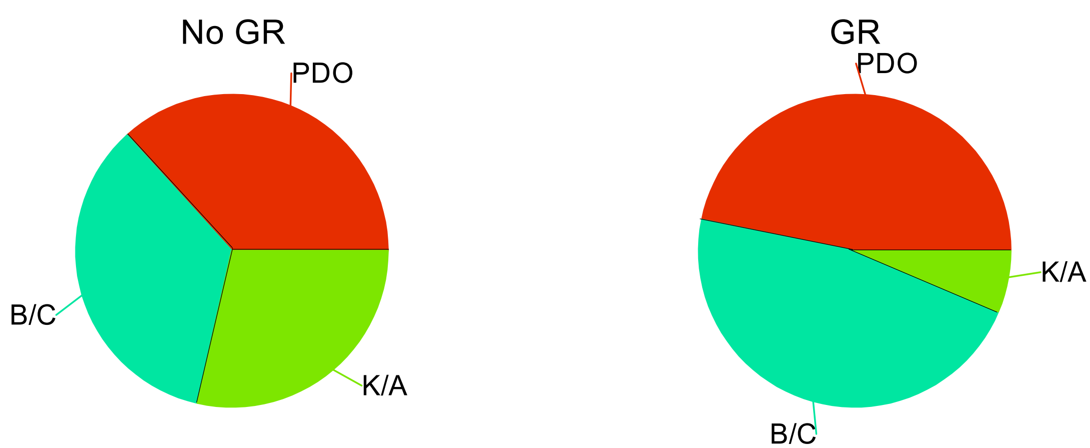


Figure 5.3. Crash Severity versus Guardrail Presence

Table 5.7 and Figure 5.3 show that crashes occurring near the CSAH bridges were significantly less severe when approach guardrail existed than when it did not exist. While guardrail did not appear to have a large effect on the proportion of B- and C-injury crashes, fatality and A-injury crashes accounted for a much smaller proportion of the crashes for bridges with approach guardrail as only three of the 47 crashes (six percent) were coded as K or A-injury. Alarmingly, 14 of the 49 crashes (28.5 percent) occurring at bridges without approach guardrail resulted in either a fatality or A-injury – <u>a rate that is 4.5 times greater</u> than at bridges where guardrail exists on the approach. Further discussion of the K and A-injury crashes analyzed here is provided in the following section.

Discussion of Fatal and Severe Injury Crashes

The researchers thoroughly investigated the crash reports for each of the 17 fatal and severe injury (i.e., A-injury) crashes that occurred near the sample bridges. Table 5.8 summarizes the attributes of these crashes.

Table 5.8. Fatal and A-Injury Crash Details

Did bridge have approach Guardrail?	2004 ADT	Crash severity	Crash type	Summary of police description	Initial object struck or first harmful event	Was guardrail effective or if guardrail did not exist, would it have been effective?
No	425	A	31	Swerved to miss deer; struck corner of bridge rail near end on approach	Bridge Rail	Potentially (Attenuation)
No	790	A	31	Lost control on slippery road, crossed centerline and side-impacted the end of the bridge rail end	Bridge Rail	Potentially (Attenuation)
No	205	A	31	Crossed centerline and struck the bridge railing head-on and continued off the roadway	Bridge Rail	Potentially (Attenuation)
No	394	A	31	Head-on strike to end of bridge rail on approach	Bridge Rail	Potentially (Attenuation)
No	1445	A	31	Head-on strike to end of bridge rail on approach	Bridge Rail	Potentially (Attenuation)
No	8846	A	31	Lost control on icy road and struck end of bridge rail head-on	Bridge Rail	Potentially (Attenuation)
No	317	A	37	Crossed centerline, ROR and struck bank of waterway	Embank-ment	Potentially (Redirection)
No	418	A	51	Swerved to miss deer, crossed centerline, ROR into ditch just ahead of bridge and rolled over	Ditch/ Rollover	Potentially (Redirection)
No	343	K	30	ROR on the right (approx. 177-ft upstream of the bridge), went into ditch, sideswiped one tree and struck another head-on, vehicle engulfed in fire	Tree	Potentially (Redirection)
No	481	K	31	Struck end of bridge rail head-on on the approach, went through the rail and into the creek; a piece of the rail went through the car	Bridge Rail	Potentially (Attenuation)
No	1507	K	31	Struck end of bridge rail head-on on the approach, railing came through cab striking driver, car flipped and came to rest in creek	Bridge Rail	Potentially (Attenuation)
No	826	K	31	ROR to left, overcorrected back to right, struck end of bridge rail with rear of veh (sheared off rear of veh), vaulted down river bank striking trees, coming to rest submerged in the river	Bridge Rail	Potentially (Attenuation)
No	833	K	31	Lost control of veh and driver side collided with end of bridge rail on approach	Bridge Rail	Potentially (Attenuation)
No	1455	K	51	Crossed centerline, ROR on left side near bridge (but did not strike), struck ditch, went airborne, and overturned	Ditch/ Rollover	Potentially (Redirection)
Yes	249	A	31	ROR onto shoulder, overcorrected back onto roadway, rolled on roadway and overturned, and struck bridge rail where veh came to rest	Bridge Rail	No (ROR on departure side where GR did not exist)
Yes	253	A	51	Crossed centerline, ROR on left side about 150-ft prior to bridge, struck ditch then tree and rolled multiple times into creek.	Ditch/ Rollover	No (ROR on departure side where GR existed but was short)
Yes	5629	K	37	ROR on the right side approximately 100-ft past bridge, went into ditch, collided with culvert wall, went airborne and landed on roof	Ditch/ Culvert	No (ROR on departure side where GR did not exist)

Table 5.8 shows that for each of the 14 fatal or severe-injury crashes at bridges without approach guardrail, the severity of those crashes could potentially have been reduced had guardrail been in place when the collision occurred. In ten of these 14 crashes, the vehicle struck the end of the unprotected bridge rail – usually head-on. Had approach guardrail been present in these cases, it would likely have either attenuated the vehicle from a direct impact on the blunt end of the rail or redirected the vehicle back onto the roadway before impacting the bridge rail. The other four crashes were a result of the vehicle running-off-the-road and striking a roadside object or rolling over. Had approach guardrail existed in these cases, it would likely have redirected the vehicle back onto the roadway, thereby preventing the more severe run-off-the-road collision.

For the three severe crashes that occurred at bridges with approach guardrail, the collisions occurred on the departure side of the bridges, which either did not have guardrail or had a section of guardrail that was too short to prevent the collision.

Crash Severity versus Initial Object Struck

Table 5.8 showed that none of the 17 fatal or severe injury crashes involved a collision with approach guardrail. All of the severe crashes were either collision with the end of the bridge rail, collision with a roadside object, or roadside rollover. Table 5.9 and Figure 5.4 show how the collision object affects crash severity. Note, "GR" also included crashes that occurred at the bridge rail/guardrail connection.

Table 5.9. Chi-Square Test for Crash Severity versus Initial Object Struck

Crash Severity	Percent Roadside	BR	GR	Total	Total Count
PDO (no injury)	36.0	34.2	54.5	41.7	40
B/C (non-incapacitating injury or possible injury)	40.0	36.8	45.5	40.6	39
K/A (fatal or incapacitating injury)	24.0	28.9	0.0	17.7	17
Total	100.0	100.0	100.0	100.0	
N	25	38	33	96	
Test statistic	Value	df	Prob		Statistically Significant Differences?
Pearson chi-square	11.452	4.000	0.022		**Yes**

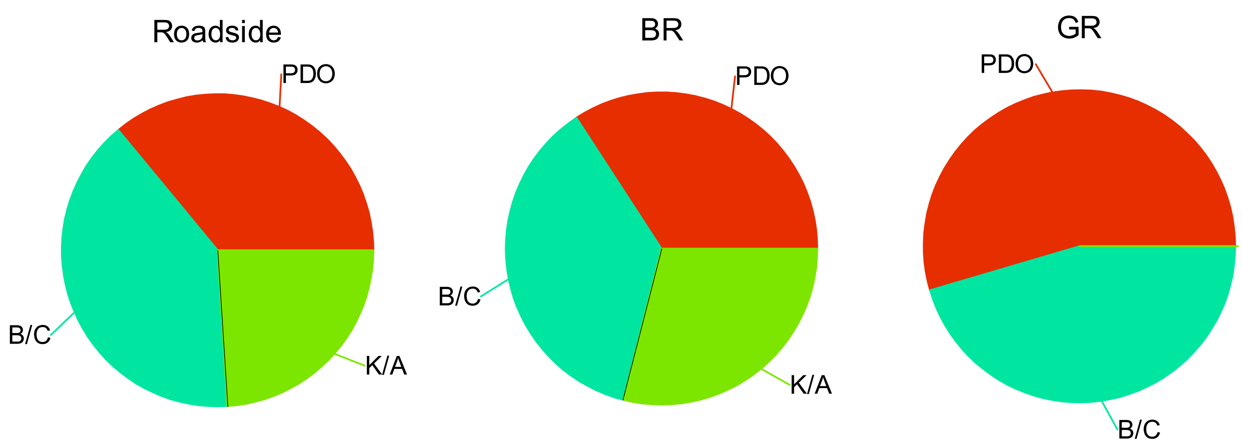


Figure 5.4. Crash Severity versus Initial Object Struck

Table 5.9 and Figure 5.4 clearly show that collision with approach guardrail resulted in a significantly lower proportion of fatalities and A-injuries and a significantly higher proportion of PDO crashes. As stated earlier, zero of the fatal and A-injury crashes involved collision with the approach guardrail. Roadside collisions and collisions with the ends of the bridge rail each resulted in similar proportions of fatalities and A-injuries (24 percent and 29 percent, respectively). The type of object struck had only a moderate effect on the proportion of B/C injuries. Importantly, the data shown in Table 5.9 and Figure 5.4 correlate very closely with the severity probabilities shown in Table 5.6 that were predicted by the logistic regression analysis.

Effectiveness of Guardrail Based on Type of Collision and Guardrail Presence

The information obtained from the police descriptions and diagrams, in most cases allowed the researchers to determine the following:

- If approach guardrail existed, was it effective in preventing a potentially more serious crash?
- If no approach guardrail existed, would guardrail have potentially reduced the severity of the crash (i.e., provided attenuation from the bridge rail end or kept the vehicle on the roadway)?

The following graphs display the findings from this analysis of the 96 crashes near the sample bridges with and without approach guardrail.

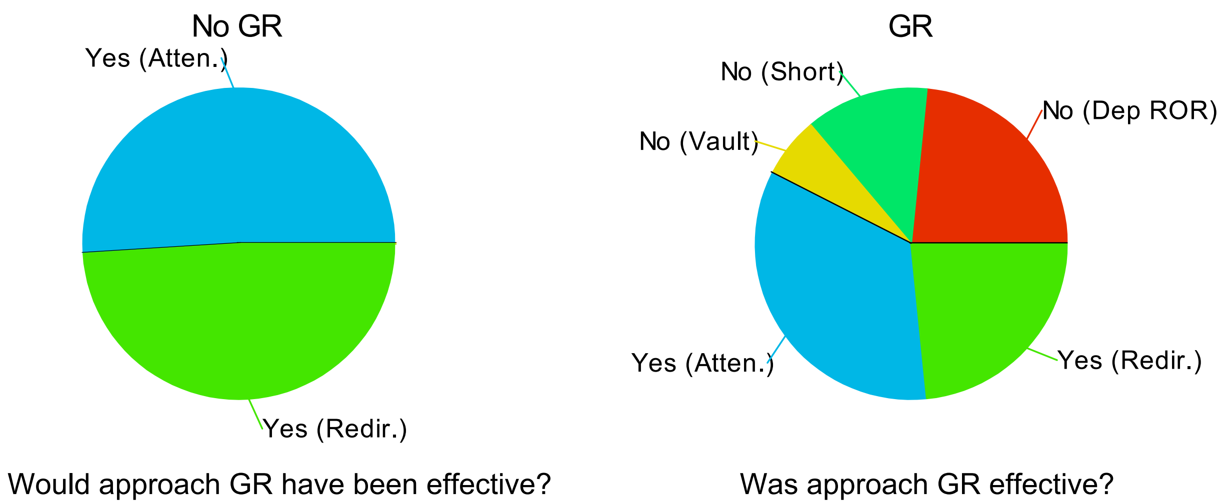


Figure 5.5. Effectiveness (or Potential Effectiveness) of Approach Guardrail

Figure 5.5 shows many important findings. First, for the 49 collisions at bridges without approach guardrail, researchers hypothesized that each crash could potentially have been less severe if approach guardrail had existed, either by redirection of the vehicle back onto the roadway or by attenuation from the bridge-rail end. For the 47 collisions at bridges with approach guardrail, the guardrail was considered effective in approximately 57 percent of the cases. The guardrail was considered effective if it provided attenuation from the end of the bridge rail or redirection back onto the roadway. The approach guardrail was deemed ineffective in roughly 43 percent of the collisions. Approach guardrail was deemed ineffective if any of the following occurred:

- The vehicle vaulted over or broke through the guardrail;
- The guardrail section was too short to protect the vehicle against running off the road; or
- The vehicle ran off the road on the departure side of the bridge where no guardrail was present (i.e., guardrail existed on the two approach corners only).

Assessment of the Need for Guardrail at All Bridge Corners versus Approach Corners Only

Based on conversations with numerous Minnesota county engineers, it appeared that the application of guardrail on all four corners of the bridge rail versus on the two approach corners only is a practice that varies from county to county. Figure 5.6 shows a comparison of guardrail protection at all corners of the bridge versus only the two approach corners.

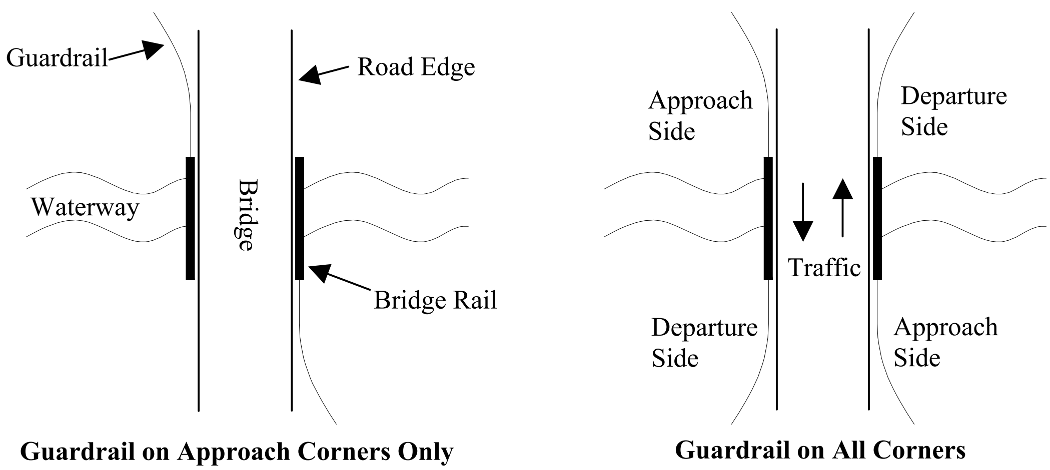


Figure 5.6. Guardrail Protection at Approach Corners Only versus All Corners

Guardrail applied at all four bridge corners is designed to protect both approach- and departure-side events. Departure-side collisions include cases where the vehicle runs off the road to the right after crossing the bridge or crosses the centerline ahead of the bridge and runs-off-the-road to the left, potentially striking the bridge rail head on. Departure-side protection is especially critical on narrow bridges. Figure 5.7 shows the occurrence of approach- versus departure-side crashes for the 96 crashes near CSAH bridges.

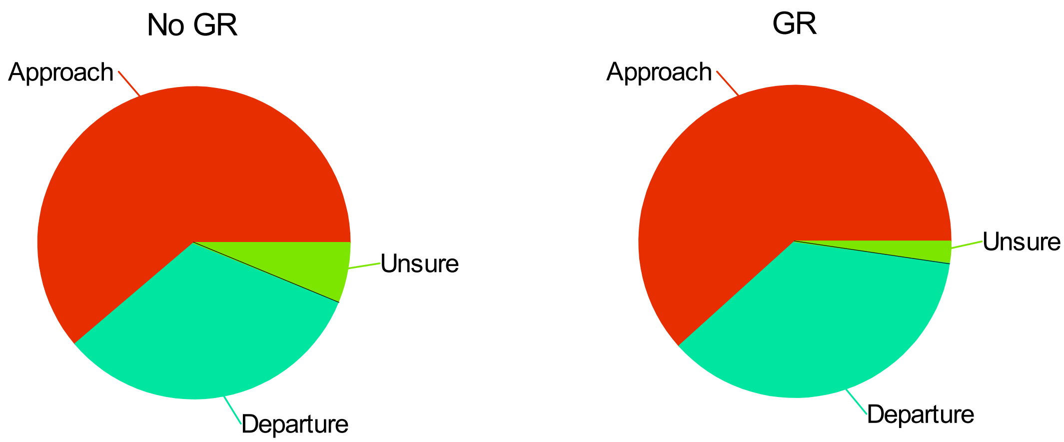


Figure 5.7. Location of First Harmful Event with Respect to Bridge

Figure 5.7 shows that, as expected, the location of the collision with respect to the bridge is not affected by the presence of guardrail. Approach-side collisions occurred in approximately 62 percent of the sample crashes, while departure-side collisions occurred approximately 34 percent of the crashes. Thus, departure-side collisions with a bridge component occur frequently enough to potentially warrant departure-side guardrail protection. Due to a lack of detail in certain collision diagrams and descriptions, the researchers were unsure of the location of initial collision in approximately four percent of the cases.

Further analysis of approach- versus departure-side collisions included comparison of guardrail effectiveness for the approach- versus departure-side collisions. This analysis was performed using only data for bridges with approach guardrail. Figure 5.8a-c shows the analysis of 29 approach-side and 17 departure-side bridge collisions at bridges with approach guardrail.

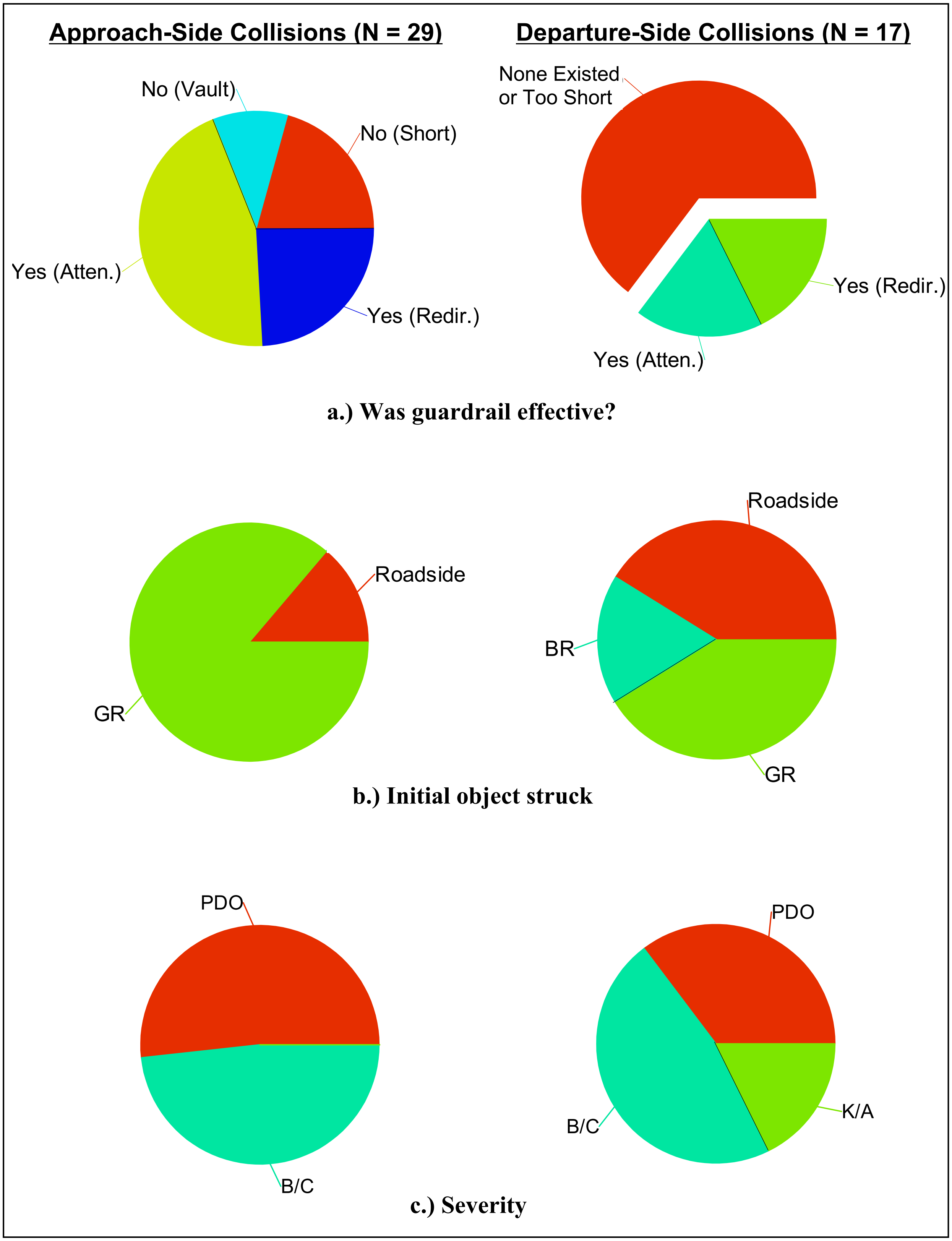


Figure 5.8. Effectiveness of Guardrail for Approach-Side versus Departure-Side Collisions for Bridges with Approach Guardrail

Figure 5.8a-c shows a number of useful findings. Looking first at the approach-side collisions, guardrail was found to be effective in approximately 69 percent of these cases. Furthermore, 86 percent of the approach-side crashes were collisions with the guardrail. Finally, slightly more than half of the approach-side collisions were property-damage only, while the rest were B- or C-injuries and, most importantly, zero were fatalities or A-injuries.

In contrast, for departure-side collisions, departure-side guardrail existed and was effective in only 35 percent. Furthermore, departure-side guardrail either did not exist or was too short to be effective in 65 percent of the departure-side collisions, with each of these crashes resulting in either a collision with the end of the bridge rail or a roadside collision. Only 35 percent of the departure-side collisions were PDO, while 18 percent were fatalities or A-injuries. The researchers deemed it important to further analyze the severity of the 17 departure-side crashes versus departure-side guardrail presence, the findings of which are shown in Figure 5.9.

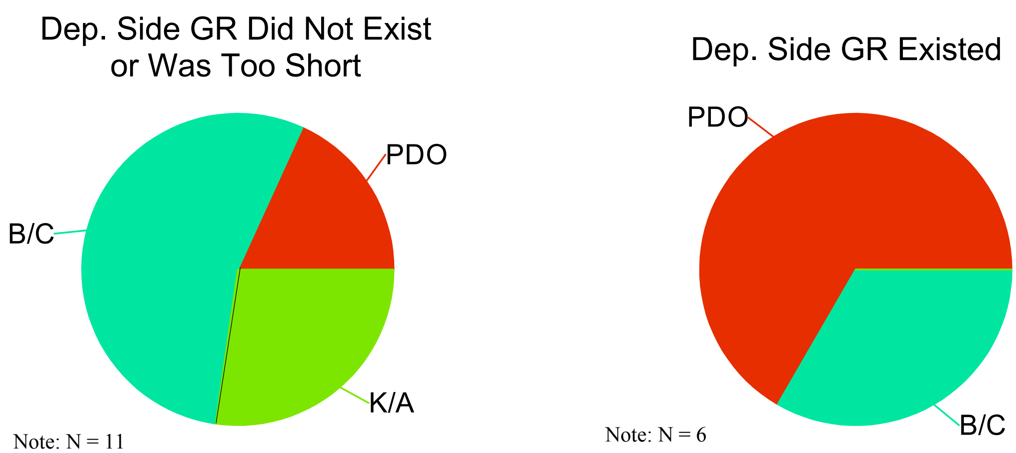


Figure 5.9. Severity of Departure-Side Collisions for Bridges with Approach Guardrail

Figure 5.9 shows that 9 of the 11 (82 percent) departure-side collisions where either no guardrail was present or it was too short to be effective resulted in either an injury or fatality (one fatality, two A-injuries, two B-injuries, and four C-injuries). It is important to note that the three K/A-injuries that occurred on the departure-side of bridges where guardrail either did not exist or was too short to be effective accounted for all of the K/A-injuries at bridges with approach guardrail (see Table 5.8).

Guardrail was present and provided effective protection for six departure-side collisions. Four of these collisions resulted in property-damage only, while the other two resulted in B- or C-injuries. Although the sample size is small, these results suggest substantial reductions in severity if guardrail protection is provided at both the approach- and departure-sides of bridges rather than at the approach-sides only.

CHAPTER 6:
BENEFIT/COST ANALYSIS

There is no debating the fact that hazardous immovable objects such as bridge abutments, piers, and railings exist within roadway clear-zones on CSAH roadways presenting a significant safety concern. Yet the installation of guardrail on these low-volume roads can add costs and other safety and maintenance problems that may outweigh the proposed benefits. Beyond the fact that guardrail itself is a fixed-object within the clear-zone, guardrail is known to promote snow drifting during the winter months and vegetation growth during summer months providing an additional maintenance and safety concerns.

Thus, a primary task of this research was to perform a benefit/cost analysis. Benefit/cost analyses are used to compare the relative benefits and costs of treatment alternatives. The objective of the analysis performed here was to determine the ADT at which the benefit/cost ratio suggests installing bridge-approach guardrail provides a positive return on investment for CSAH bridges in Minnesota. In other words, the researchers sought to identify the ADT where the benefit/cost ratio exceeds 1.0.

COSTS OF APPROACH GUARDRAIL

Any benefit/cost analysis begins with determination of the potential costs (i.e., materials, labor) and benefits (i.e., crash savings). The first step in the analysis was to determine an approximate life-cycle cost for a typical section of approach guardrail. Conversations with numerous Mn/DOT employees allowed the researchers to develop an approximate life-cycle cost for a typical installation of approach guardrail to all four bridge corners. Costs for bridge-approach guardrail include those for:

- Installation
    - standard guardrail,
    - transition guardrail,
    - end treatment,
    - supplementary signs and/or delineators,
    - labor;
- Maintenance
    - vegetation removal,
    - snow removal; and
- Repair.

It was reasonable to assume that the guardrail has no salvage value at the end of its useful life. The estimated life-cycle was 30 years, although this may be greater if steel posts are used instead of wood. Because maintenance and repair costs will occur sometime after installation, they were first converted to present-worth. Mn/DOT's Office of Investment Management recommends using a 3.6 percent annual discount rate (*7*), which represents the interest rate minus inflation rate for a 30-year U.S. Treasury note or bond. The estimated 2004 costs for installation, maintenance, and repair of approach guardrail for a single Minnesota CSAH bridge is shown in Table 6.1. The corresponding cash-flow diagram is shown in Figure 6.1. The 2004 cost per bridge for bridge-approach guardrail assuming a 30-year design-life and protection at all four corners was estimated at $27,100 - $45,000 with approximately $14,400 - $20,000 (roughly 40 – 60 percent) of that being the cost of materials and labor for installation.

Table 6.1. 2004 Costs for Approach Guardrail on a CSAH Bridge

Category	Item	Unit Cost	Minimum Section Length	Total Cost per Bridge (All 4 Corners)	Net 2004 Cost
Initial Installation (Including Labor)	Standard Guardrail	$12-$15 /ft	50 ft	$2,400-$3,000	$2,400-$3,000
	Transition Guardrail	$36-$50 /ft	25 ft	$3,600-$5,000	$3,600-$5,000
	End Treatment	$2,000-$3,000 /ea.	1 unit	$8,000-$12,000	$8,000-$12,000
	Supplementary Object Markers	$100 /ea.	1 unit	$400	$400
	Salvage	$0	-	$0	$0
	Total Installation				$14,400 - $20,000
Additional Maintenance	Vegetation Removal, Snow Removal	$100 /yr	-	$100- $500 /yr	$1,800- $9,100
Repair	Replacement of 1 section every 5 years due to vehicle or farm equipment hit	$3,600-$5,100 /5 yr	-	$3,600-$5,100 /5 yr	$10,900- $15,500
Total Life-Cycle Cost					**$27,100- $45,000**

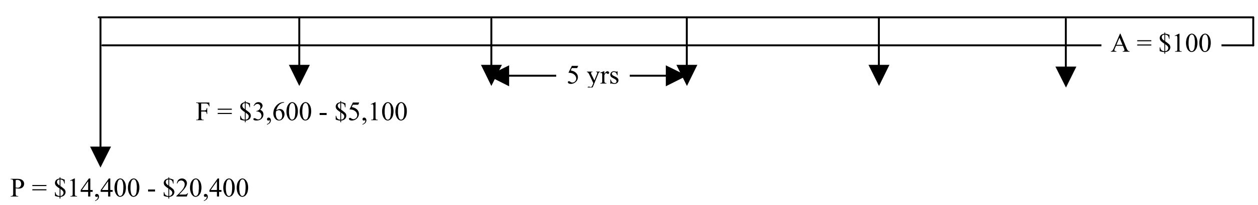


Figure 6.1. Cash-Flow Diagram for Cost of Approach Guardrail on a CSAH Bridge

BENEFITS OF APPROACH GUARDRAIL

The primary benefit for installing approach guardrail is a reduction in the costs of target crashes (i.e., crashes with bridge components, run-off-the-road near the bridge, etc.). Crash costs can be reduced either through a reduction in the severity and/or frequency of such crashes. For bridges without approach guardrail, typical crashes may include the following:

- ROR - bridge component
    - bridge rail (including blunt ends),
    - curb,
    - pier, or
    - abutment;
- ROR - roadside
    - rollover,
    - tree,

- embankment,
- ditch,
- culvert/headwall, or
- pole/post.

Based on the results of the crash analysis, installation of bridge-approach guardrail is expected to greatly reduce the occurrence of all types of roadside collisions and collisions with bridge components – especially the blunt ends of the bridge rail. These crashes would typically be replaced by a less-severe collision with the guardrail. The analysis also showed that the severity of crashes near bridges will be lower if approach (and departure) guardrail exists. The reduction in crash severity will consequently result in a net crash cost savings. Mn/DOT's Office of Investment Management maintains a list of estimated crash costs for each severity level (based on the KABCO scale), which are summarized in Table 6.2 (*7*).

Table 6.2. 2004 Minnesota Crash Costs versus KABCO Severity

Crash Severity	Estimated Cost per Crash (2004 dollars)
Property Damage Only	$4,300
C Injury (Possible Injury)	$29,000
B Injury (Non-Incapacitating Injury)	$59,000
A Injury (Incapacitating Injury)	$270,000
Fatal	$3,500,000

As can be observed in Table 6.2, any treatment that can reduce a crash from a fatality to an A-injury has a net positive economic impact of $3.23 million. A treatment that reduces crash severity from an A-injury to a B-injury has a net positive economic impact of $211,000, and so forth for the remaining severity reductions. Therefore, the analysis focused on quantifying differences in crash severity that could be attributed to approach guardrail.

ANALYSIS AND FINDINGS

The analysis was performed using data from the same 96 run-off-the-road and fixed-object bridge crashes used in the crash analysis described in Chapter 5. The 96 crashes were separated by 2004 ADT, crash severity, and guardrail presence and placed in a series of tables along with the estimated crash costs from Table 6.2. Table 6.3 summarizes the crash frequencies by ADT category, severity, and guardrail presence.

Table 6.3. Bridge Crashes from 1988-2002 by ADT, Severity, and Guardrail Presence

	Bridges		PDO		C		B		A		K		TOTAL	
2004 ADT	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR
<150	63	6	3	0	0	0	1	0	0	0	0	0	4	0
150-399	72	21	4	3	1	0	1	0	3	2	1	0	10	5
400-749	51	25	4	1	1	0	5	3	2	0	1	0	13	4
750-999	12	15	1	0	1	1	1	1	1	0	2	0	6	2
1000-1499	17	21	4	5	3	4	0	3	1	0	1	0	9	12
1500-4999	16	29	0	5	0	1	0	0	0	0	1	0	1	6
5000-9999	5	20	1	3	1	1	1	3	1	0	0	1	4	8
10000<	7	18	1	5	0	2	1	3	0	0	0	0	2	10
All	243	155	18	22	7	9	10	13	8	2	6	1	49	47

Using the data from Tables 6.2 and 6.3, the total crash costs for each of the ADT categories were computed for bridges with and without approach guardrail. Because the traffic volumes varied from bridge to bridge, it was important to normalize the crash costs on a per-vehicle basis. The estimated cumulative traffic volumes for the 1988-2002 analysis period were generated based on the reported ADTs and the 2004 traffic growth factors (shrink factors in this case) for each county. Figure 6.2 presents a summary of the estimated crash costs (2004 dollars) per one hundred million (10^8) vehicle crossings based on ADT category and guardrail presence. These results exist in tabular-format in Appendix H.

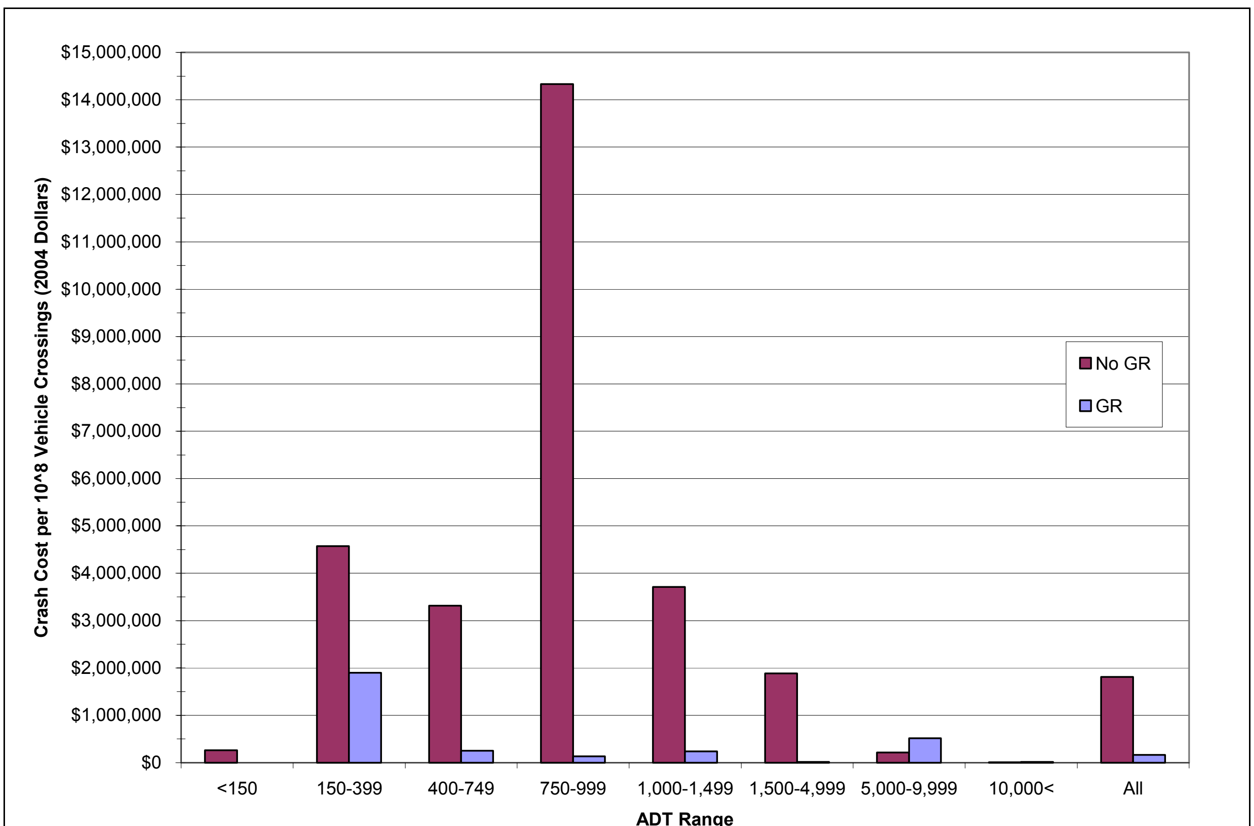


Figure 6.2. Crash Costs per 10^8 Vehicle Crossings by ADT Range and Guardrail Presence

Figure 6.2 shows a number of important findings. First, for all bridges with ADT less than 5,000 vpd, the crash costs per vehicle crossing are considerably higher at bridges without approach guardrail than at bridges with approach guardrail. This is especially true for the 750-999 vpd category where bridges without approach guardrail have crash costs that are 105 times those of bridges with approach guardrail. This is largely due to the disproportionate number of K and A-injury crashes occurring in this ADT range at bridges without approach guardrail. When all bridges are considered, the crash cost-per-vehicle-crossing is approximately 11 times greater for bridges without approach guardrail than for bridges with approach guardrail.

The findings shown in Figure 6.2 and Appendix H were used to estimate the crash benefits for each ADT range. In a practical sense, a crash benefit can be thought of as the estimated reduction in crash costs that would be expected if approach guardrail was installed at bridges where no guardrail existed. Although such values cannot truly be determined, they can be estimated based on the costs of crashes that occurred at the cohort sample of bridges with approach guardrail.

Furthermore, because approach guardrail costs were computed for a 30-year life-cycle, the benefits were also computed for the same 30-year term from 2004 to 2034. Three 30-year cumulative traffic volume forecasts, which can be found in Appendix I, were created for use in the benefit/cost analysis based on the estimated 2004 ADTs for each bridge and the following growth rates:

- No traffic growth during the 30-year period;
- 30-year traffic based on the 2004 estimated traffic growth rate per county (Anoka 1.5%, Crow Wing 1.7%, Dakota 1.4%, Fillmore 1.3%, Goodhue, 1.6%, Lyon 1.3%, Mower 1.2%, Olmsted 1.6%, Rock 1.2%, Wantowan 1.3%); and
- 30-year traffic based on a 2 percent annual growth rate.

The 30-year crash benefits for installing approach guardrail were then computed by multiplying the per-vehicle crash costs for bridges without approach guardrail (in 2004 dollars as shown in Figure 6.2) by an estimate of the cumulative number of vehicle crossings at these bridges for the 30-year period of 2004 to 2034. Three estimates of the benefits were computed for each ADT category based on the three traffic forecasts and are displayed along with the low and high approach guardrail costs in Figure 6.3 and in tabular-format in Appendix I.

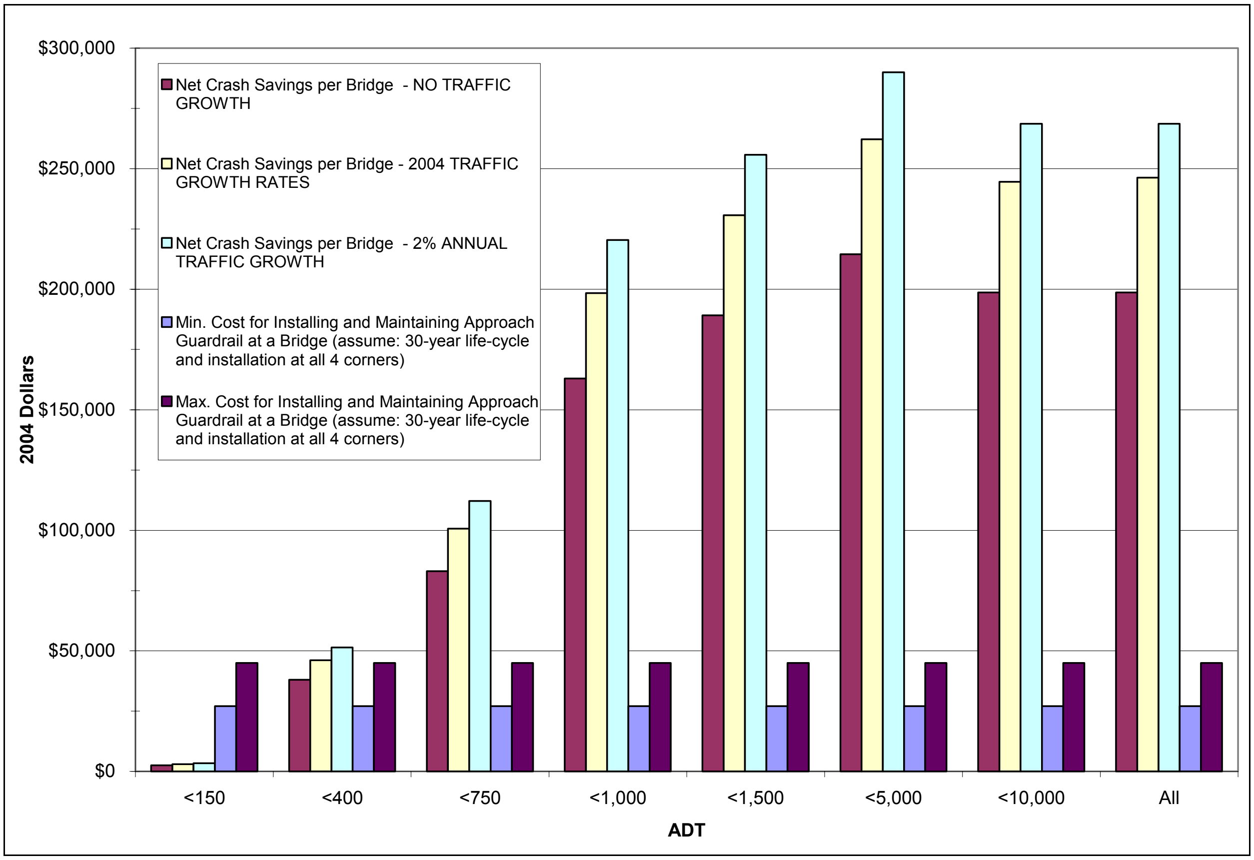


Figure 6.3. Estimated Crash Savings and Costs per Bridge if Approach Guardrail is Installed

The data in Figure 6.3 were used to compute a benefit/cost ratio for each ADT category using the equation that follows. Table 6.4 displays a summary of the benefit/cost calculations, while the full procedure can be found in Appendix I. The results are displayed in Figure 6.4a-b.

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\dfrac{\text{Crash Savings}}{\text{Vehicle}} \times \dfrac{\text{\# Vehicles}}{\text{\# Bridges}}}{\dfrac{\text{Crash Costs}}{\text{Vehicle}} \times \dfrac{\text{\# Vehicles}}{\text{\# Bridges}} + \dfrac{\text{GR Costs}}{\text{Bridge}}} \tag{7}$$

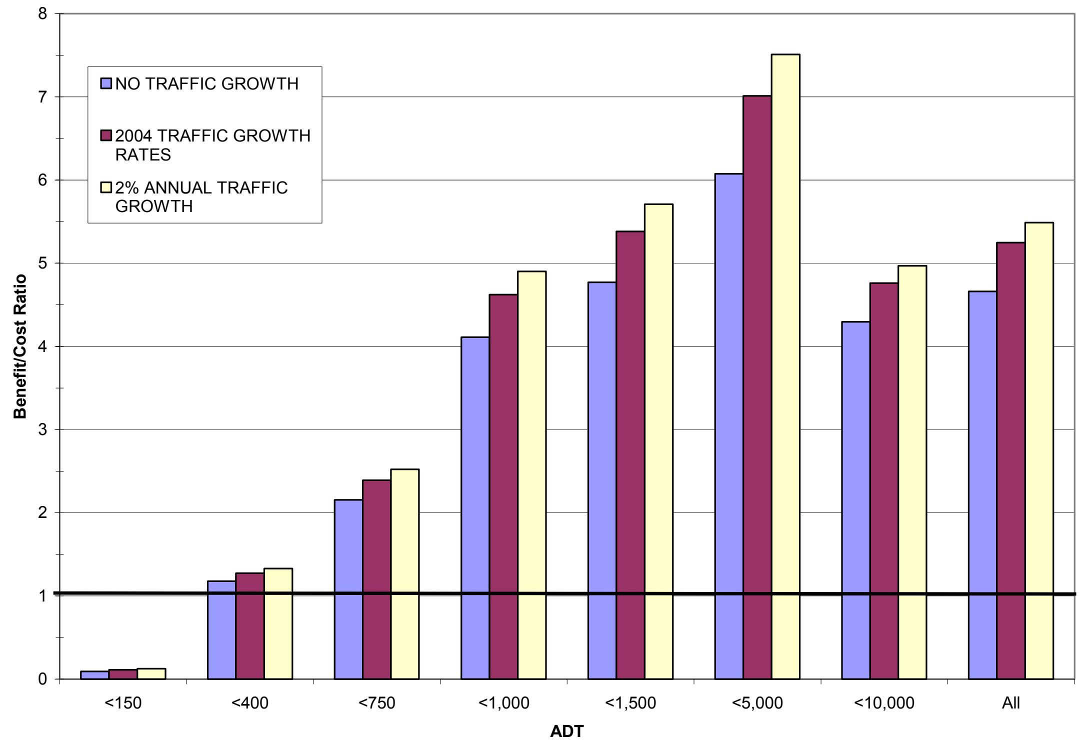
Where: Crash Savings/Vehicle = 30-year estimated crash savings per vehicle that would occur if approach guardrail is added to bridges previously without guardrail (2004 dollars)
Crash Costs/Vehicle = 30-year estimated crash costs per vehicle for bridges with approach guardrail (2004 dollars)
Vehicles = 30-year cumulative traffic volume for bridges without approach guardrail
Bridges = number of bridges without approach guardrail
GR Cost/Bridge = 30-year life-cycle cost of approach guardrail per bridge (2004 dollars)

Table 6.4. Benefit/Cost Calculations for Bridge-Approach Guardrail (2004 Dollars, 30-year Life-Cycle)

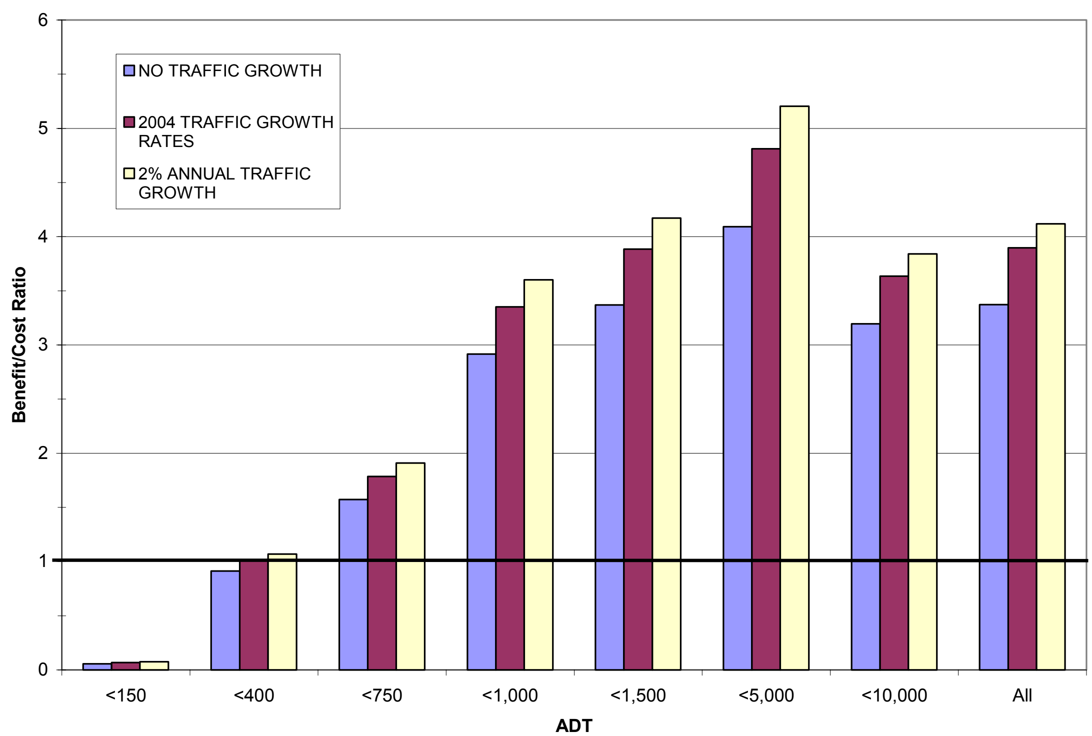
				Benefits	Costs		B/C Ratio	
Traffic Growth	ADT	Cumulative 30-year Traffic	Bridges Without GR	Total 30-year Crash Savings per Bridge if GR is Applied	Min. Total 30-year Costs per Bridge if GR is Applied[a]	Max. Total 30-year Costs per Bridge if GR Applied[b]	**Min**	**Max**
None	<150	59,554,131	63	$2,497	$27,100	$45,000	**0.06**	**0.09**
	<400	270,678,691	135	$72,680	$61,743	$79,643	**0.91**	**1.18**
	<750	560,103,092	186	$104,319	$48,423	$66,323	**1.57**	**2.15**
	<1,000	673,435,068	198	$179,599	$43,695	$61,595	**2.92**	**4.11**
	<1,500	902,932,388	215	$205,050	$42,975	$60,875	**3.37**	**4.77**
	<5,000	1,312,120,407	231	$224,324	$36,927	$54,827	**4.09**	**6.07**
	<10,000	1,687,691,045	236	$223,613	$52,060	$69,960	**3.20**	**4.30**
	All	*2,932,663,571*	*243*	*$218,440*	*$46,864*	*$64,764*	***3.37***	***4.66***
2004 Rates	<150	72,219,261	63	$3,027	$27,100	$45,000	**0.07**	**0.11**
	<400	327,977,731	135	$88,065	$69,076	$86,976	**1.01**	**1.27**
	<750	679,637,910	186	$126,582	$52,974	$70,874	**1.79**	**2.39**
	<1,000	819,740,831	198	$218,618	$47,300	$65,200	**3.35**	**4.62**
	<1,500	1,101,206,922	215	$250,076	$46,461	$64,361	**3.89**	**5.38**
	<5,000	1,604,359,858	231	$274,286	$39,116	$57,016	**4.81**	**7.01**
	<10,000	2,077,635,497	236	$275,279	$57,827	$75,727	**3.64**	**4.76**
	All	*3,635,725,478*	*243*	*$270,807*	*$51,602*	*$69,502*	***3.90***	***5.25***
2% Annual	<150	80,533,223	63	$3,376	$27,100	$45,000	**0.08**	**0.12**
	<400	366,030,486	135	$98,283	$73,946	$91,846	**1.07**	**1.33**
	<750	757,410,220	186	$141,067	$55,935	$73,835	**1.91**	**2.52**
	<1,000	910,665,573	198	$242,867	$49,541	$67,441	**3.60**	**4.90**
	<1,500	1,221,007,755	215	$277,282	$48,568	$66,468	**4.17**	**5.71**
	<5,000	1,774,340,153	231	$303,346	$40,389	$58,289	**5.20**	**7.51**
	<10,000	2,282,212,800	236	$302,385	$60,853	$78,753	**3.84**	**4.97**
	All	*3,965,750,934*	*243*	*$295,389*	*$53,826*	*$71,726*	***4.12***	***5.49***

Notes: [a] Includes estimated crash costs and $27,100 installation and maintenance costs (for 30-year life-cycle, 2004 dollars)

[b] Includes estimated crash costs and $45,000 installation and maintenance costs (for 30-year life-cycle, 2004 dollars)



a. B/C Assuming <u>Minimum</u> Life-Cycle Cost for Installing Approach Guardrail



b. B/C Assuming <u>Maximum</u> Life-Cycle Cost for Installing Approach Guardrail

Figure 6.4. Benefit/Cost Ratio Based on Threshold ADT and Traffic Growth Rate

Table 6.4 and Figure 6.4 show that for ADT less than 150 vpd, the benefit/cost ratio for bridge-approach guardrail is very small (i.e., < 0.10) regardless of the forecasted traffic growth rate or guardrail costs. For ADT less than 400 vpd, the benefit/cost ratio ranges between 0.9 and 1.3 depending on the traffic growth rate and guardrail installation costs. The benefit/cost ratio for approach guardrail increases steadily as the ADT threshold is increased above 400 vpd.

For bridges with ADT between 150 and 399 vpd, further analysis was necessary to determine the cost-effectiveness. Closer investigation of the one fatal and three A-injury crashes at bridges without guardrail in this ADT range showed that only one A-injury and no fatalities occurred for ADTs between 150 and 299 vpd. The remaining three severe crashes occurred at bridges with ADTs between 300 and 399 vpd. As a result, the researchers split this ADT range into 150-299 vpd and 300-399 vpd and re-ran the benefit/cost analysis. Figure 6.5 displays the benefit/cost ratios for each of these ADT ranges along with the two adjacent ADT ranges (<150 vpd and 400-749 vpd).

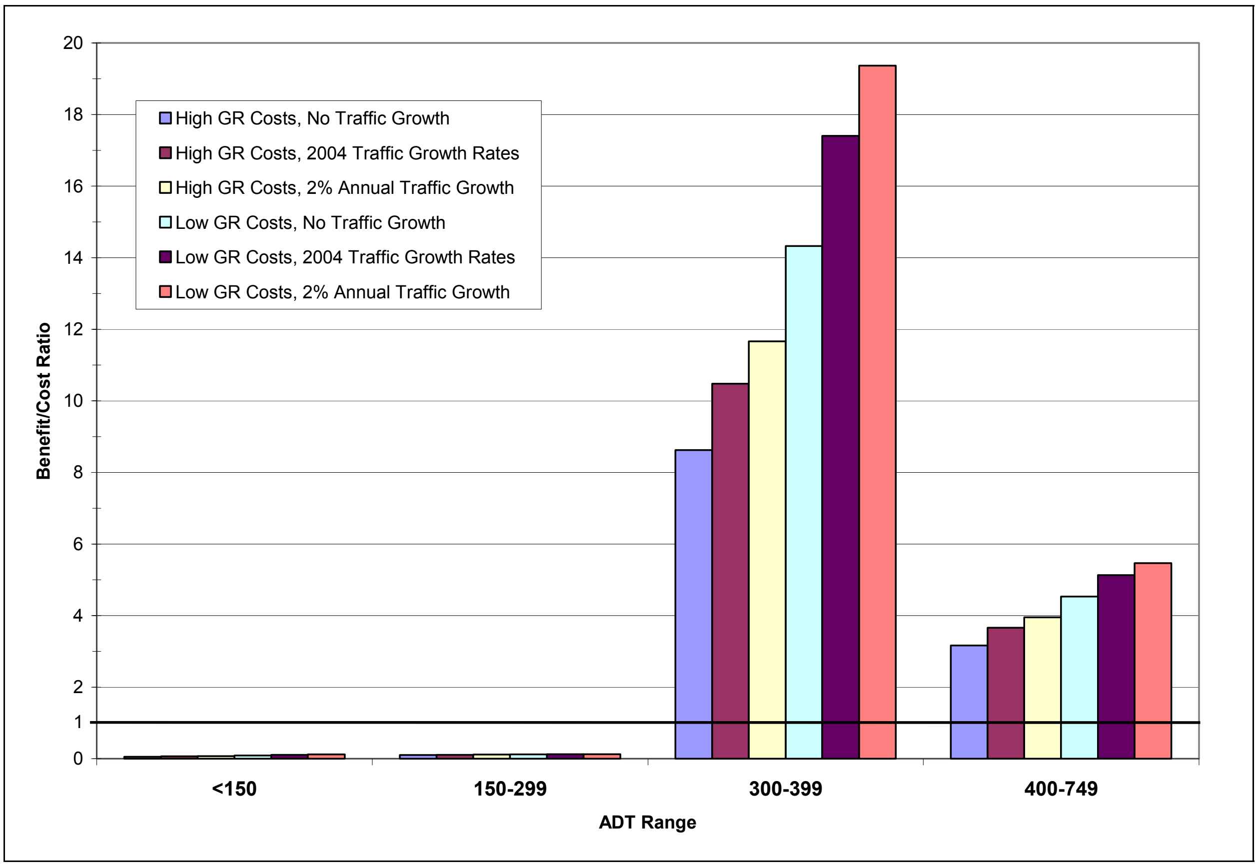


Figure 6.5. Revised Benefit/Cost Ratios for Bridges with ADT between 0 and 750 vpd

Figure 6.5 shows that approach guardrail is not cost-effective for CSAH bridges with ADT less than 300 vpd, but is highly cost-effective for CSAH bridges with ADT greater than or equal to 300 vpd. Figure 6.6 displays the benefit/cost ratios for the revised cumulative ADT thresholds for the maximum guardrail costs only.

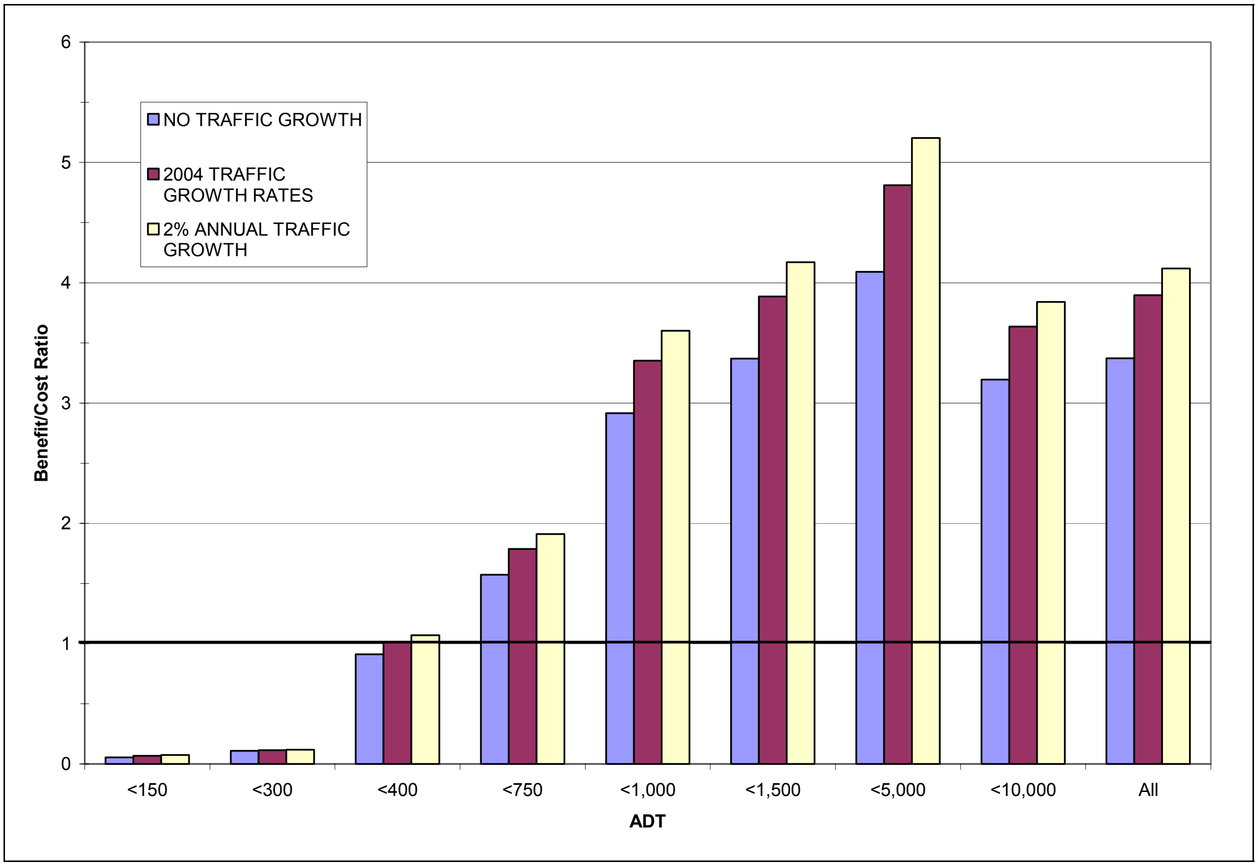


Figure 6.6. Benefit/Cost Ratio Based on Revised Threshold ADT for Guardrail Installation

CHAPTER 7:
CONCLUSIONS AND RECOMMENDATIONS

The major objective of the research described herein was to determine if the presence of approach guardrail had an effect on both the type and severity of crashes occurring near a ten-county sample of Minnesota CSAH bridges. The initial tasks included a literature review and survey of state agency practice, which produced little data related to the safety or cost-effectiveness for bridge-approach guardrail. The primary tasks included analysis of Minnesota crash data to determine the safety and cost-effectiveness of approach guardrail for CSAH bridges and to determine ADT-based criteria for bridge-approach guardrail on the CSAH system.

The initial data analyses focused solely on queries from the Minnesota crash database. The final database query included a total of 263 run-off-the-road and fixed-object crashes occurring between 1988 and 2002 and within approximately 200 feet of any of the 398 CSAH bridges included in the sample. Analysis of the crash database queries was limited because collisions with approach guardrail and all other bridge components were coded into the crash database under a single code (TYPE 31 "bridge piers") and included no further information about the object struck. As a result, the effectiveness of approach guardrail could not be determined based solely on the crash database information and thus required a detailed review of the respective police crash-reports.

The researchers reviewed the diagrams and descriptions from the crash reports of 238 of the 263 crashes from the database query. Upon review of the crash report, a crash was considered to be appropriate for use in the analyses if the crash:

- Occurred on the approach or departure and within approximately 200 ft of the appropriate CSAH bridge; and
- Involved collision with a bridge component (including approach guardrail), roadside fixed-object, or other roadside collision.

The screening process resulted in 96 of the initial 238 crash reports being deemed useful to the analyses, 47 of which occurred near bridges with approach guardrail, while the remaining 49 crashes occurred at bridges without approach guardrail. Comprehensive safety analyses and benefit/cost analyses were performed on the sample of 96 crashes. The conclusions and recommendations from these analyses are summarized in the sections that follow.

CONCLUSIONS

Mn/DOT Practice Compared to Other Agencies

Twenty-six of the 35 state agencies responding to the survey (74 percent) have policies or guidelines requiring the placement of approach guardrail or attenuators on state-aid bridges. Only Wisconsin, Illinois, and Virginia have policies similar to Minnesota's in that bridge-approach guardrail is required on state-aid local highways only where an ADT threshold is exceeded. These states' ADT thresholds ranged from 150 to 750 vpd. Six of the responding agencies also indicated that lower-speed facilities (i.e., speeds ≤ 45 mph) do not require approach guardrail. Agencies were rather evenly split between use of an attenuator versus a minimal or modified section of guardrail when insufficient guardrail space exists.

Effect of Approach Guardrail on Crash Severity

The analyses showed that bridge-approach guardrail was effective at reducing the severity (and subsequent costs) of run-off-the-road crashes occurring on the approach or departure to CSAH bridges. While guardrail did not appear to have a large effect on the proportion of B- and C-injury crashes, the proportions of fatal and A-injury crashes were considerably lower when guardrail existed on the approach. Fatal or A-injury crashes accounted for only six percent of the crashes occurring at bridges with approach guardrail, but accounted for 28.5 percent of the crashes at bridges without approach guardrail - a rate that is 4.5 times greater than at bridges with approach guardrail.

As previously presented in Figure 5.4, further analysis of the severity of various object-types struck showed that collisions with approach guardrail resulted in a significantly lower proportion of fatal and A-injury crashes when compared to collisions with the bridge rail or other roadside collisions. In fact, zero of the 33 approach guardrail collisions were fatal or A-injuries. This statistic is even more significant when compared to roadside and bridge rail collisions of which 24 percent and 29 percent, respectively, were fatalities or A-injuries. These findings were statistically validated by both a chi-square analysis and logistic regression analysis.

Effectiveness of Approach Guardrail

A section of approach guardrail was deemed effective if it either provided attenuation from the end of the bridge rail or redirection back onto the roadway or shoulder. The guardrail was deemed ineffective if a vehicle vaulted over or broke through the section, if it was too short to prevent a vehicle from running off the road, or if no guardrail existed at the corner of the bridge where the crash occurred. The researchers determined that all of the 49 collisions at bridges without approach guardrail could potentially have been less severe if approach guardrail had existed at the time of the crash.

Approach guardrail was effective in approximately 57 percent of the 47 collisions at bridges with approach guardrail, either by attenuation or redirection. However, the approach guardrail was found to be less effective or ineffective in roughly 43 percent of the collisions, although the researchers concluded that each of these cases could have been prevented. For example, cases of vehicles vaulting over or breaking through the guardrail could have been avoided with the use of upgraded end-treatments and improved guardrail designs, respectively. Cases where the vehicle ran-off-the-road just ahead or beyond the guardrail could have been prevented by longer guardrail sections. Finally, cases where guardrail existed only on the two approach corners but a vehicle ran-off-the-road on the departure side of the bridge would have been aided if departure-side guardrail had been installed.

Guardrail Protection at All Corners of Bridge versus Approach Corners Only

The analysis showed that approach-side collisions occurred in approximately 62 percent of the crashes near CSAH bridges, while approximately 34 percent of the collisions were departure-side collisions (undetermined in 4 percent of the cases). For approach-side crashes at bridges with approach guardrail, the guardrail provided effective attenuation or redirection in 69 percent of the cases with no A-injuries or fatalities. However, departure-side guardrail either did not exist or was too short to be effective in 65 percent of the departure-side collisions at bridges where approach-side guardrail existed. Alarmingly, 82 percent of these departure-side collisions where either departure-side guardrail was not present or it was too short to be effective resulted in either an injury or fatality.

Crash Coding for Collisions with Bridge Components

The Minnesota crash reporting system does not included a specific code for either bridge rail or approach guardrail, rather both were typically included in TYPE 31 "bridge piers", which represented crashes with any component of the bridge, including approach guardrail. A detailed review of the police diagrams/descriptions showed that none of the 67 crashes coded as TYPE 31 were actually pier strikes. Instead, all of the 67 crashes coded in the database as TYPE 31 were found to be either collision with bridge rail or approach guardrail.

Cost-Effectiveness of Approach Guardrail

The benefit/cost analysis showed that typical installations of bridge-approach guardrail (i.e., approximately 75 ft of rail and end treatments installed at all four bridge corners) are cost-effective (i.e., B/C > 1) for CSAH bridges with ADT greater than or equal to 300 vpd, becoming increasingly more cost-effective with increasing ADT. However, bridge-approach guardrail is generally not cost-effective for CSAH bridges with ADT less than 300 vpd. Overall, approach guardrail installed on CSAH bridges has a benefit/cost ratio of approximately 3.5 to 5.5 depending on assumptions for traffic growth rate and guardrail costs. The benefit/cost ratios for approach guardrail installation at various ADT thresholds were presented previously in Table 6.4 and Figures 6.4 and 6.6.

RECOMMENDATIONS

ADT Threshold for Installation of Approach Guardrail on CSAH Bridges

The primary goal of this research was to determine the appropriate ADT threshold at which approach guardrail is cost-effective at CSAH bridges. The safety analysis showed significantly lower rates of severe crashes at bridges with approach guardrail versus those without for all ADTs except the very low ranges. The subsequent benefit/cost analysis showed that approach guardrail was cost-effective (i.e., B/C > 1) at all bridges except those with ADTs less than 300 vpd.

Given the limited number of bridges in the 300 to 400 vpd range, the researchers recommend that the ADT threshold for approach guardrail on CSAH bridges be set at 400 vpd. In other words, all CSAH bridges with ADT greater than or equal to 400 vpd should have approach guardrail. A threshold ADT of 400 vpd is consistent with previous Mn/DOT standards and AASHTO guidelines (*2*). It is recommended that bridges with ADT between 150 and 400 vpd, especially those between 300 and 400 vpd, be reviewed on a case by case basis for guardrail need. Bridges located on horizontal curves and with bridge deck widths less than the approach roadway may warrant guardrail at ADT between 150 and 400 vpd. Placement of approach guardrail at bridges with ADT less than 150 vpd is probably not cost-effective for a vast majority of the cases.

Guardrail Protection at All Corners of Bridges

Although only about 1/3 of all collisions analyzed here were departure-side collisions, the researchers recommend application of guardrail at all four corners of the bridge rail instead of only at the two approach corners. This practice has traditionally varied from county to county but installation at all four corners appears to now be occurring more frequently. Guardrail applied at all four bridge corners provides protection for both approach- and departure-side events, such as where the vehicle runs off the road to the right after crossing the bridge or crosses the centerline ahead of the bridge and runs-off-the-road to the left, potentially striking the bridge rail head-on. Departure-side protection is especially critical for narrow bridges.

Crash Type Coding for Collisions with Bridge Components

To reduce the ambiguity that exists in the current crash coding system for collisions with bridge components and guardrail, the researchers recommend splitting the current crash TYPE 31 “bridge pier” and TYPE 34 “guardrail” into the following four distinct categories (also assigning an arbitrary numeric code):

- “Bridge pier/abutment”,
- “Bridge rail”,
- “Bridge guardrail (approach or departure)”, and
- “Other guardrail (not attached to bridge)”.

REFERENCES

1. American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide* (Washington, D.C.: AASHTO, 2002).

2. American Association of State Highway and Transportation Officials (AASHTO), *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* (Washington, D.C.: AASHTO, 2001).

3. L.B. Stephens, *A User's Guide to Guardrail Warrants for Low-Volume Roads, Report NCHRP 22-5A* (Washington, D.C.: National Research Council, April 1992).

4. J.W. Hall, "Guardrail Installation and Improvement Priorities," *Transportation Research Record 868*, (1982), 47-53.

5. W.A. Schwall, *Upgrading of Bridge-Approach Guardrail on Primary Roads in Iowa* (Ames, IA: Federal Highway Administration, Iowa Division, 1989).

6. D. Wolford and D.L. Sicking, "Guardrail Need: Embankments and Culverts," *Transportation Research Record 1599,* (1997).

7. Mn/DOT Office of Investment Management (Internet), *Benefit/Cost Analysis for Transportation Projects,* July 2004 (cited January 2005), http://www.oim.dot.state.mn.us/EASS/ (see Table 1).

APPENDIX A

State Survey Form

University of Wisconsin Survey: Application of Guardrail on Bridge Approaches for Low Volume Roads

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AGENCY:
NAME:
DIVISION:
PHONE:
EMAIL:

1. Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low-volume state and local roads?

If Yes:
- i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
- ii. How was this ADT threshold developed?
- iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

If No: What is the basis for placement of guardrail on bridge approaches for local roads?

2. Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

3. Does your agency use treatments other than guardrail to protect bridge abutments?

If Yes, please describe:

4. Is the basis for guardrail placement a state/agency policy or simply a guideline?

5. Has this policy/guideline been recently changed or considered for change?

If Yes, why?

6. Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low-volume roads?

If Yes, how can we obtain a copy of the report?

7. May we receive:

- i. A copy of the current application policy/guideline
- ii. A copy of the current design standard for bridge-approach guardrail?

APPENDIX B

State Survey Responses

Full Agency Responses

=========

Agency: Ohio Dept. of Transportation
Name: Dean Focke
Division: Office of Roadway Engineering
Phone: 614-466-2847
Email: dfocke@dot.state.oh.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Ohio does recognize AASHTO's 2001 Guidelines for Geometric Design of Very Low Volume Local Roads, but only for county and municipal projects. The state system cannot use that AASHO Guideline (very little meets that ADT criteria and is considered a local road). Therefore, all facilities that are constructed with state or federal money must comply with ODOT standards which are based on a speed threshold of 50 mph for approach guardrail placement.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Only difference we allow is between low speed and high speed facilities. Protection on low speed facilities on city streets and urban type facilities is normally not required.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: When deflection would be a problem, concrete barrier is used. In certain high accident locations, Impact Attenuators could be substituted for guardrail and guardrail transitions.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Just to allow AASHTO's Very Low Volume Guidelines on county/local roads.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

Question 7a: Policy - ODOT's Location and Design Manual is found on-line at:
http://www.dot.state.oh.us/roadwayengineering/LDM1_link.htm
Section 600 is on Roadside Safety.

Question 7b: Standards - ODOT's Standard Drawings for Guardrails are found on-line at:
http://www.dot.state.oh.us/roadwayengineering/standard_drawingslink.htm
Guardrail drawings for bridge approaches are GR-6.a and 6.2.

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Agency: Nebraska Department of Roads
Name: Phil TenHulzen
Division: Roadway Design
Phone: (402) 479 - 3951
Email: ptenhulz@dor.state.ne.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All highways constructed with Federal and State moneys receive guardrail attached to bridge rail.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

=========
Agency: CONNDOT
Name: DANIEL GLADOWSKI
Division: DESIGN
Phone: 860-594-3280
Email: Daniel.Gladowski@po.state.ct.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: If state/federal money was used to construct the bridge, it must follow the state standard and have guardrail on the approach, regardless of the system. Municipalities are encouraged to use Department guiderail standards. These can be obtained on our website, ct.gov/dot under Publications, see Highway Design Manual - Chapter 13.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Illinois Department of Transportation
Name: Gary Galecki
Division: Highways-Bureau of Local Roads and Streets
Phone: 217-785-8564
Email: galeckigj@nt.dot.state.il.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: 150 ADT on a local road for a federal-funded project provided the roadway is on a tangent alignment. Also, when the distance between the bridge rails is greater than two time the clear-zone for ADTs 0-400, guardrail on the departure sides of the bridge is not required.

Question 1ii. How was this ADT threshold developed?
Answer: Based on a policy committee including representatives of the Illinois Department of Transportation Bureau of Local Roads & Streets, county engineers and municipal engineers.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: Not to our knowledge. The design of lane widths, shoulders, etc. are based on a different ADT. A copy of our design guidelines for rural roadways is attached.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: As stated above, if the ADT is at least 150 and on a tangent alignment, guardrail is required. If the roadway is not on a tangent alignment, it is required regardless of the ADT.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: Yes. Illinois has a township (road district) road system within each county. Most of these roads are low volume with oil and chip or aggregate surfaces. If the road district bridge is wider than the existing roadway and on a tangent alignment, guardrail is not required.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: No

Question 3a: If Yes: Please describe:

Answer: Not for local low volume roads. Also, please note that when guardrail is used on low volume local roads, typically a Type 1A barrier is used as an end treatment. Attached is a copy of our standard.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: Please note that the policy we refer to is for local roads using federal funds.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: Yes

Question 5a: If Yes, why?

Answer: Our department's local roads policy manual is currently being revised. The chapter for roadside safety has not been drafted, but this policy will be reviewed. We anticipate to have the new manual completed at the end of this year.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: Yes

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Agency: Illinois Department of Transportation (IDOT)

Name: David L Piper
Division: Highways/Bureau of Design and Environment
Phone: (217)785-0720

Email: piperdl@nt.dot.state.il.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?

Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: See separate response from our Local Roads Bureau.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: No response.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: No

Question 3a: If Yes: Please describe:

Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: See our Bureau of Design Manual, online at: http://www.dot.state.il.us/desenv/bdemanual.html For Roadside Safety Policy (New/Reconstruction) see: Ch 38-4.09. For 3R (Other than Freeway) see Ch 49-3.07(d). For 3R (Freeway) see Ch 50-3.09. For a statement on low speed (<30 mph) urban sections see Ch 38-3.02(f). This availability of documents online is to be considered as positive response to last two questions. Design Standards and Specifications are available at: http://www.dot.state.il.us/desenv/demanuals.html

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: Yes

Question 5a: If Yes, why?

Answer: Statement in Ch 38-3.02(f) recently updated to conform with Roadside Design Guide.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Maine Department of Transportation
Name: Leanne Timberlake
Division: Bridge Program
Phone: 0207-624-3422
Email: leanne.timberlake@maine.gov

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We place guardrail on all bridge approaches, including those on local roads. However, we do have reduced standards based on AADT for determining the length of guardrail and the type of end treatment on local and collector roads. For example, if the ADT is less than 500, a low-volume end treatment may be used.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: The only time I can envision not having guardrail on a bridge-approach is in an urban setting where the edge of a building butts up against the end of the bridge rail.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: On rare occasions, we might use fencing in addition to guardrail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: The guardrail and guardrail policy was updated for NHS and other state roads in July 2003 to be NCHRP 350 compliant for new construction. New AADT levels were set for the selection of guardrail end treatment on non-NHS state roads: NCHRP 350 compliant for AADT =>500, Low Volume Guardrail End for

AADT <500. We are currently in the process of developing new standards for guardrail lengths and end treatments with bridges on local roads.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

=========

Agency: Mississippi Department of Transportation
Name: Wes Dean, P.E.
Division: Traffic Engineering Division
Phone: 601-359-1454
Email: wdean@mdot.state.ms.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: N/A

Question 1ii. How was this ADT threshold developed?
Answer: N/A

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: N/A

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We install guardrail on all MDOT maintained bridges, including state-aid local road bridges.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes
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Agency: New Jersey Department of Transportation
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Division: Structural Engineering
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All state bridges must have approach guardrail. Local roadway bridges must follow this policy if state or federal money is used.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: N/A This response reflects only State roads.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes
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Agency: Delaware DOT
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Division: Transportation Solution, Bridge Section
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Design speed. For the design speed up to 35 mph, we allow tapered down parapet. Otherwise all bridges built with state/federal monies must have approach guardrail.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Yes, mainly clear-zone. If the slope is greater than 3:1 than approach guardrail must be placed.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: Guideline

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No, but we review and implement FHWA guidelines, and the crash test results

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Oklahoma DOT
Name: Faria Emamian, P.E
Division: Traffic Engineering
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: We are using the Min distance of Clear-zone (see Table 3.1 Road side Design Guide)

Question 1ii. How was this ADT threshold developed?
Answer: Based on National Study (AASHTO)

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Bridge approaches are considered a hazard. All state bridges are protected with approach guardrail and any local bridges that were built with state monies are also protected at the same level. We calculate the guard rail for bridge approaches based on length of need which takes in to account the approach slopes, ADT, shy line, distance to the bridge-approach, and clear-zone distance.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: YES

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Yes, Most cases we are using Guard Rail, but there is some situation that we are using crash cushioning type devices like Quad Gard or Tracc etc if the bridge is too close to an immovable object.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Based on the newest requirement from FHWA(which is based on crash tests) Guard rail Block out and Bridge connection has been changed to satisfy the latest crash test requirements.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Arkansas Highway and Transportation Department
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Division: Roadway Design
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridge ends are protected regardless of AADT, including state-aid local bridges. The clear-zone requirement follows the AASHTO Roadside Design Guide.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: See response under 1b.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: In curb and gutter sections, bridge ends are protected with a concrete parapet transition wall. Also, other bridge end treatments such as "Trend Systems" (i.e. crash cushions) are used if existing driveways or intersecting roadways are positioned too close to a bridge to use guardrail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: See response to 1b.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: No

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Agency: Virginia Dept. of Transportation
Name: Bryant Lowery
Division: Engineering Services Section of Location and Design Div.
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?

Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: ADT less than or equal to 400 vpd as a general guide.

Question 1ii. How was this ADT threshold developed?

Answer: Defined by AASHTO in the 2001 Guidelines for Geometric Design of Very Low-Volume Roads.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: The VDOT Road Design Manual (available online) uses ADT along with other factors to determine paving, shoulders, etc.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: Each - Pay limits are from the terminal end treatment, or standard strong post guardrail at the point where the post spacing begins to decrease, to the physical attachment on the bridge.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: Yes. Typical items we look at other than ADT are: speed, accident history, paved/unpaved roadway, room for guardrail, can guardrail be physically attached to an older bridge, cost, hazards other than bridge, would bad situation become worse with addition of guardrail which itself is a hazard.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:

Answer: Delineation, Impact Attenuators

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: Other

Question 4a: If Other, please describe:

Answer: For low-volume roads, each location is handled on a case by case basis. Good engineering judgment must be used to determine if guardrail should be used on bridge-approach.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: No

Question 5a: If Yes, why?

Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: No

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: Yes

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Agency: Iowa Department of Transportation
Name: Will Stein
Division: Methods Engineer
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: Yes for low volume county roads ~ 200 ADT. No for state roads, we shield all bridge ends.

Question 1ii. How was this ADT threshold developed?
Answer: Used the cost effective selection procedure given in AASHTO's 1977 Guide for selecting, locating, and designing traffic barriers.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: Yes, must also have a structure width of 24' or greater, must be on a tangent alignment, and the benefit/cost ratio is less than 0.80.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: For local county roads see County Engineers I.M. 3.213. This is available on-line at : http://www.dot.state.ia.us/local_systems/publications/county_im/county_im_toc.htm.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Occasionally we use impact attenuators if there is insufficient room for guardrail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: For local/county roads ~ I.M. 3.213 may be updated in the future as per AASHTO'S policy for very low volume local roads. The current edition of I.M. 3.213 does not account for the latest AASHTO guidance. For state roads, no.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Nevada Department of Transportation
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Division: Specifications/Standards and Manuals
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We have adopted the the AASHTO Roadside Design Guide as a criteria for justifying all roadside design issues regardless of the type of facility. The Roadside Safety Analysis Program is used to analyze benefits and costs in conjunction with engineering judgment to make decisions.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Please refer to the AASHTO Roadside Design Guide. In addition, the funding source may be a factor.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: First of all we do not normally install safety hardware to protect bridge components. We use safety hardware to shield traffic from the blunt ends of bridge rails along with the feature that the bridge is crossing if the feature itself is an obstacle. In conjunction with guardrail we use a transition section to eliminate the coffin corner effect at the bridge rail end and then a guard rail end terminal to protect traffic from the end of the guardrail. If the feature that the bridge crosses is not an obstacle itself then a crash cushion is acceptable to protect traffic from the blunt end of the bridge rail. For abutments I assume you are referring to when traffic is running under the bridge. In these cases we use guardrail or concrete barrier rail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: Other

Question 4a: If Other, please describe:
Answer: It is actually a combination of the two. The AASHTO Roadside Design Guide is adopted as a guide however we also have policy regarding the placement of safety hardware also.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: The latest edition of the Roadside Design Guide was issued in 2003.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Michigan Department of Transportation
Name: Mark C. Harrison
Division: Highways
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We have all bridges use guardrail on bridge approaches.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: In urban settings where guardrail cannot be placed and the traffic speed is low (25mph) a sloped concrete end section has been used.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Michigan has yet to adopt the low volume road manual. However, when it does, which should be shortly, the state is making a policy that all bridge ends must be protected.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: West Virginia Department of Transportation (Response 1)
Name: Ray Lewis
Division: Traffic Engr. Div., Division of Highways
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We attempt to put adequate approach guardrail on all bridges on local roads. In some cases, we can go to the point of need; however, we try to get 62.5 feet of guardrail on each corner. In cases where speeds are low this may be w-beam guardrail with 12' 6" post spacing, no blockouts, and buffer ends.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No response.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: No
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Agency: West Virginia Department of Transportation (Response 2)
Name: Randy Epperly
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Phone: 304-558-6266
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Many issues are considered including speed, height of the roadway, types of vehicles, roadway alignment

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: See above

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Concrete barriers in certain situations.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Rhode Island Department of Transportation
Name: David A. Craveiro,P.E.
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Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: No, we protect all bridges, including state-aid local bridges. Use AASHTO Roadside Design Guide for clear-zone.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:

Answer: Crash cushions such as Sand Barrels or expandable guardrail systems with cells are also used at abutments and gore abutments on bridge ramps.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: Other

Question 4a: If Other, please describe:

Answer: RIDOT uses the Roadside Design Guide, the AASHTO Green Book Design Guide and also develops standards which are base on our those design standards and performance experiences in the field with installations.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: Yes

Question 5a: If Yes, why?

Answer: Only in the sense that it is upgraded and adjusted to account for newer guidelines and standards developed under the auspices of the National Cooperative Highway Research Program. NCHRP 350 is the latest and adjustments are made when necessary.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: No response.

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: No response.

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Agency: Kansas Department of Transportation

Name: Ron Seitz
Division: Bureau of Local Projects
Phone: (785)296-3861
Email: seitz@ksdot.org

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?

Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: On city/county road projects we require a minimum length of guardrail (approach transition plus crashworthy terminal) as a minimum on all bridges regardless of how low the traffic volumes are. We are only protecting the end of the bridge rail and do not consider the full clear-zone.

On state highway projects, approach guardrails will be used in accordance with the Roadside Design Guide (length of need) regardless of traffic volumes.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: No other factors. We place approach guardrail in all cases.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:

Answer: In urban areas a tapered approach concrete barrier may be used, particularly when there is a sidewalk present. This design reduces maintenance concerns, is more aesthetically pleasing, and is safer for pedestrians because it eliminates the sharp edges and/or projections that are present on a guardrail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: No

Question 5a: If Yes, why?

Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: Yes

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Agency: Utah Department of Transportation

Name: Boyd Wheeler / Glenn Schulte
Division: Structures/ Traffic & Safety
Phone: 801-964-4456 801-9654376
Email: bwheeler@utah.gov gschulte@utah.gov

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?

Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: AASHTO Roadside Design Guide clear-zone requirements dictate requirements for need for protection.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:

Answer: Precast or cast in place concrete barrier or appropriate attenuation.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Tennessee Department of Transportation (Paper copy only)
Name: Ed Wasserman
Division: Structures
Phone: 615-741-3351
Email: ed.wasserman@state.tn.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridges, regardless of system or finding source are fitted with NCHRP 350 approved bridge rails and approach guardrails.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: None

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: Other

Question 4a: If Other, please describe:
Answer: TnDOT subscribes to following AASHTO policy as defined in the standard specifications for highway bridges and the LRFD specifications for design of highway bridges, which call for crash tested rails to given crash levels. TnDOT and FHWA agree on this.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: See 4a., above.

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes (attached)

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Agency: Wisconsin DOT
Name: Pat Fleming (via telephone, entered by TG)
Division:
Phone: 608-266-8486
Email:

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: 300 for all state-aid roads. Length of guardrail determined by AASHTO RDG clear-zone calculations.

Question 1ii. How was this ADT threshold developed?
Answer: AASHTO RDG recommends ADT of 400, also AASHTO DG for Very Low Volume Roads, TRB Special Report 214.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: Speed: Urban state-aid routes with curb and gutter and sidewalk with design speed less than or equal to 45 mph do not need guardrail.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Crash cushions directly affixed to bridge rail if the space is too confined to place guardrail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: Chapter 11-45-1 of the WisDOT Design Manual (follows AASHTO RDG for clear-zone).

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No response.

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: TxDOT
Name: Rory Meza (via telephone, entered by TG)
Division: Roadway Design
Phone: 512-416-2678
Email:

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridge rails/parapets must be protected including off-system state/federal aid bridges

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: Curve guardrail back if need be (70' min needed for straight section of g.r.)

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No response.

Question 6a: If yes, how can we obtain a copy of the report?
Answer: Possibly TTI or CTR - call Mark Vawshawk 512-416-2178

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No response.

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: No response.

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Agency: Mn/DOT
Name: Paul Stine
Division: State Aid for Local Transportation
Phone: (651) 296-9973
Email: paul.stine@dot.state.mn.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: 750

Question 1ii. How was this ADT threshold developed?
Answer: By consensus of county engineer standards committee.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: Yes, ADT defines standards ranges.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Yes, design speed greater than 40 mph.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: Other

Question 4a: If Other, please describe:
Answer: Rule (has the force and effect of law).

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Was raised from 400 ADT to 750 ADT in 2000.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: SDDOT
Name: Noel Clocksin (via telephone, entered by Tim)
Division: Local Roads
Phone: 605-773-4256
Email: noel.clocksin@state.sd.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No, but ADT is used to determine the type of guardrail used

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No bridge rail is left completely unprotected. Local Rural Roads with ADT's less than 150 have only rail end treatments turned down and connected directly to the bridge. Will mail me standard drawings.

Question 1ii. How was this ADT threshold developed?

Answer: Will email me information

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: This particular ADT was chosen because it was determined that in most cases in South Dakota, local roads below 150 are gravel and above 150 are asphalt. This basically is our line between low volume and high volume local roads in South Dakota.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: No response.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?

Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:

Answer: Attenuators if no space for GR

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: No

Question 5a: If Yes, why?

Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: Standards: http://www.sddot.com/pe/roaddesign/plans_rdmanual.asp - State Manual http://www.sddot.com/fpa/lga/docs/secondaryroadplan.pdf - Local State Aid

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: Mailed

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Agency: Maryland State Highway Admin
Name: Tom Hicks
Division: Traffic
Phone: 410.787.5825
Email: thicks@sha.state.md.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Safety - all bridges are so provided

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Nearby intersecting roads may affect the design, possibly resulting in a short barrier wall appropriately angled

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Barrier wall, as described above

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.
Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

Dick Langoni (Taken by Tim over the phone) has submitted a survey.

Details:
=========
Agency: Colorado DOT
Name: Dick Langoni (Taken by Tim over the phone)
Division: Traffic Region 5
Phone: 970-385-1416
Email:

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridges receiving state funds regardless of system must follow the state guidelines and thus must have guardrail on approach to protect the blunt ends.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No response.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Washington State Dept. of Transportation
Name: Rick Glidden
Division: Design
Phone: (360) 705-7246
Email: glidder@wsdot.wa.gov

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: We are usually concerned with State Highways, not local roads.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: We usually apply full design standards at bridge approaches. Sometimes existing conditions will warrant not upgrading the barrier systems. Historic bridges or roadways with posted speed limits below 35 MPH are some examples.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: Concrete Barrier, Impact Attenuators

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Some of the WSDOT Std. Plans for guardrail transitions to bridges were revised to include a curb about one year ago to satisfy concerns raised by the Federal Highway Administration.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Arizona DOT
Name: Terry H. Otterness, P.E.
Division: ITD
Phone: 602-712-4285
Email: totterness@dot.state.az.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: There is no separate policy for local roads. Bridge ends are considered a fixed object without protection. We use either an extended barrier or most times is a thrie-beam transition to a guard rail terminal.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Not at this time.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:

Answer: Assuming we are talking about bridge dadoes or bridge ends. Crash cushions are sometimes used in special applications where access roads are too close to the bridge to allow proper guard rail length.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:

Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?

Answer: No

Question 5a: If Yes, why?

Answer: No but I think that some consideration should be given for urban conditions where curb and gutter are present and there is sidewalk across the bridge. In those conditions, there may be some justification for not introducing barrier at a bridge end.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?

Answer: No

Question 6a: If yes, how can we obtain a copy of the report?

Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?

Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?

Answer: Yes

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Agency: North Dakota DOT

Name: George Stelzmiller (recorded by Tim over phone)
Division: Design
Phone: 701-328-2556
Email: gstelzmi@state.nd.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?

Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?

Answer: No response.

Question 1ii. How was this ADT threshold developed?

Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?

Answer: All bridges, all routes if state/federal monies (AASHTO RDG)

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: ADT, Speed limit determines the length - follows AASHTO RDG

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No
Question 3a:	If Yes: Please describe:
Answer: No response.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: Guidelines/standards are online: http://www.state.nd.us/dot/designmanual.html

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Montana DOT
Name: Duane Williams
Division: Traffic and Safety
Phone: 406-444-7312
Email: duwilliams@state.mt.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?

Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridges regardless of ADT or class (see Q2 for exceptions)

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: Very low volume roads or low speed urban are case-by-case and may be excluded, but this is rare

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: crash cushion where space is limited

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: Guideline

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: Guidelines likely online

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Wyoming DOT
Name: Mike Gustovich
Division: Traffic and Safety
Phone: 307-777-4492
Email: mike.gostovich@dot.state.wy.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridges that receive state/federal money must have approach guardrail (clear-zone requirements follow AASHTO RGD)

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: No

Question 3a: If Yes: Please describe:
Answer: bend rail back where not enough space, particularly with draining ditches

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: Guideline

Question 4a: If Other, please describe:
Answer: follow AASHTO RDG strictly

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: No

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Agency: Oregon DOT
Name: Dan MacDonald (via telephone, entered by Tim)
Division: Design Standards
Phone: 503-986-3779
Email: daniel.j.macdonald@odot.state.or.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All NHS require approach guardrail. All non-NHS routes (ODOT or off-system): approach guardrail is recommended but it's up to the local engineer (ODOT or county/city) to decide based on weighing the injury risk versus the cost of the guardrail.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: volume and operating speed - is a rail cost effective given the injury risk?

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: but only if space is insufficient for guardrail

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: Guideline

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: ODOT used to protect all bridges, but recently was interested in the need for placement of approach guardrail on low volume or low speed non-NHS routes. Dan MacDonald contacted FHWA's Dick Powers (richard.powers@fhwa.dot.gov 202-366-1320) who suggested the guideline in 1b. FHWA suggests states develop their own policy.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: No response.

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: No response.

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: No response.

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Agency: NCDOT
Name: Dewayne Sykes
Division: Design
Phone: 919-250-4016
Email: dsykes@dot.state.nc.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: Yes

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.
Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: ADT < 400 a minimal section of guardrail is typically placed on most bridges to protect the rail, but there are cases such as low speed urban where exceptions may occur. (400 ADT is in conjunction with AASHTO DG for very low volume roads). Some sort of protection is generally required for all bridges. Over 400 ADT, guardrail is placed and RDG is followed.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: ADT, speed, functional classification

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: attenuators where limited space

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: www.doh.dot.state.nc.us/preconstruct/highway/dsn_srvc/value/manuals (Design Manual Part 1 - Chapter 3 Guard Rail)

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Idaho DOT
Name: MIlford Miller
Division: Design Standards
Phone: 208-334-8475
Email: mlmiller@itd.state.id.us

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: All bridges must have guardrail regardless of jurisdiction if state/federal monies are used

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: On lower speed routes (35 mph) in urban areas, use of a turned down end treatment is allowed rather than NCHRP 350 treatment

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: attenuators where space is limited

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: Yes

Question 5a: If Yes, why?
Answer: Low volumes were considered for change, but decided to keep the policy for all bridges

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: http://www.itd.idaho.gov/manuals/Design/index.htm

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Missouri DOT
Name: Joe Jones (taken over phone by Tim)
Division: Design Division, Technical Support Engineer
Phone: 573-751-3813
Email: joseph.jones@modot.mo.gov

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Policy says no blunt ends in clear-zone - therefore protect every bridge rail regardless of jurisdiction or ADT or speed as long as state or federal monies are involved.

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No response.

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?
Answer: Yes

Question 3a: If Yes: Please describe:
Answer: wrap guardrail around the radius or modify the end of the bridge to connect an impact attenuator directly to the rail.

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?

Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: Standards are on-line but manuals are not: http://www.modot.state.mo.us/business/

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: Louisiana DOT
Name: Paul Fossier
Division: Assist State Bridge Design Engineer
Phone: 225-379-1323
Email: pfossier@dotd.louisiana.gov

Question 1: Does your agency use average daily traffic (ADT) to determine whether or not guardrail should be placed on bridge approaches for low volume state and local roads?
Answer: No

Question 1a. If Yes: i. What is the minimum ADT threshold that requires for placement of bridge-approach guardrail?
Answer: No response.

Question 1ii. How was this ADT threshold developed?
Answer: No response.

Question 1iii. Does this ADT threshold coincide with any other threshold (i.e., paving, shoulders, lane width, edgelines, etc.)?
Answer: No response.

Question 1b. If No: What is the basis for placement of guardrail on bridge approaches for local roads?
Answer: Require guardrail on all bridges based regardless of ADT or system if state funding is used (follow AASHTO RDG)

Question 2: Are there other factors that play a role in the decision to place/not place approach guardrail on bridge approaches for local roads (e.g., roadway width, roadway geometry, shoulder presence/width/type, speed limit, paved vs. unpaved, etc.)?
Answer: No

Question 3: Does your agency use treatments other than guardrail to protect bridge abutments?

Answer: Yes

Question 3a: If Yes: Please describe:
Answer: yes - fit in shorter section of guardrail, YUMA treatment (curved guardrail), crash cushion if not enough space

Question 4: Is the basis for guardrail placement a state/agency policy or simply a guideline?
Answer: State/Agency Policy

Question 4a: If Other, please describe:
Answer: No response.

Question 5: Has this policy/guideline been recently changed or considered for change?
Answer: No

Question 5a: If Yes, why?
Answer: No response.

Question 6: Has your agency performed any research into the safety or benefit/cost of bridge-approach guardrail placement on low volume roads?
Answer: No

Question 6a: If yes, how can we obtain a copy of the report?
Answer: www.dotd.lousiana.gov goto publications manuals (bridge manual)

Question 7a: May we receive a copy of the current application policy/guideline?
Answer: Yes

Question 7b: May we receive a copy of the current design standard for bridge-approach guardrail?
Answer: Yes

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Agency: FHWA
Name: Dick Powers
Division: Office Safety and Design, Highway Engineer
Phone: 202-366-1320
Email: richard.powers@fhwa.dot.gov

FHWA only requires that guardrail be placed on federally funded roadways (i.e. NHS). For the case of non NHS roadways, they would like to see all bridges protected, but states are allowed to develop their own policy for non NHS roads and it's probably not cost-effective to protect every bridge. If a threshold is used, it should be based on operating speeds rather than traffic volume. Other factors include: bridge width (compared to roadway width) and presence of trees and other hazards. For example, if a wide bridge has moderate speeds, sufficient delination and object markers and has a considerable line of trees or other hazards on the approach, then it may not make sense to place guardrail on the approach.

APPENDIX C

Iowa Procedure for Determining the Need for Bridge Guardrail on Low-Volume Roads

INSTRUCTIONAL MEMORANDUMS (I.M.)

To County Engineers

To County Engineers	Date November 2001
From Office of Local Systems	IM No. 3.213
Subject Traffic Barriers (Guardrail and Bridge Rail)	

The purpose of this I.M. is to provide guidelines for determining the need for traffic barriers at roadway bridges and culverts. A traffic barrier is a device used to shield a roadside obstacle that is located on the right-of-way within an established minimum width clear-zone (see I.M. 3.215 for clear-zone instruction).

Roadside obstacles are classified as non-traversable objects (such as large culverts) and as fixed objects (such as unprotected ends of bridge rails). These roadside obstacles should first be reviewed for possible removal or relocation outside the Clear-zone. If this is not practical, then a traffic barrier may be necessary. A traffic barrier itself poses some risk to an errant motorist and should be installed only if it is clear that the barrier reduces the severity of potential crashes.

GUARDRAIL (Approach Guardrail):

In general, guardrail should be installed at:

1. All four bridge corners on newly constructed bridges on the Farm-to-Market system, except bridges located within an established speed zone of 35 mph or less.

2. On the approach bridge corners (right side) on new federally funded bridges constructed on the area service system, except bridges within a 35 mph or less speed zone. Consideration should be given to shielding the opposite corner if it is located on the outside edge of a curve. The FHWA will participate in guardrail at all four corners if desired by the county.

3. All four bridge corners on existing bridges within the termini of a 3R project on the Farm-to-Market System. Existing w-beam installations that are flared and anchored at both ends may be used as constructed without upgrading to current standards.

4. Culverts with spans greater than six feet (circular pipe culverts greater than 72" in diameter), if it is impractical to extend beyond the clear-zone and grates are not utilized.

Design exceptions (see I.M. 3.218 for design exception instructions) to not utilize guardrail at bridges or culverts will be considered if the following conditions exist:

1. Current ADT at structure is less than 200 vehicles per day.

2. Structure width is 24' or greater.

3. Structure is on tangent alignment.

4. Benefit/cost Ratio is less than 0.80.

Other obstructions, within the right-of-way and clear-zone, should be reviewed for removal, relocation, installation of a traffic barrier or the "do nothing" option based on a cost-effectiveness approach.

BRIDGE RAILS (Barrier Rail):

Bridge rails on newly constructed bridges should be constructed to the latest available standards (includes SL-1 type rail on structures with less than 1,000 vpd). On bridge rehabilitation projects involving federal-aid, any substandard bridge rail should be reviewed for retrofitting.

Bridge rails which are both structurally deficient and functionally obsolete should be reviewed for upgrading as part of the 3R projects. Included with this I.M. is a "Bridge Rail Rating System" developed to assist in determining if a bridge rail should be upgraded with the 3R project and to what extent it should be upgraded. Any bridge which is programmed in the near future for replacement or rehabilitation may not require upgrading as part of the 3R project.

The rating system assigns points to five factors (Crashes, ADT, Width, Length and Type of bridge rail); the sum of these factors will indicate the degree or amount of upgrading required, if any. The crash factor involves crashes (property damage only, personal injury and fatality) in the last five years (Access ALAS). The types of bridge rail are from various county bridge standards. If the existing rail is not an old standard, then determine which type it is similar to and assign the corresponding points.

Consideration should be given to extending the guardrail through the bridge on short bridges or bridges which have no end posts. This may be less costly than attaching the guardrail as per standard RE-27B or constructing an end post.

BRIDGE RAIL RATING SYSTEM

5 FACTOR SYSTEM

POINTS	**0**	**5**	**10**	**15**	**20**
Crashes (in the last 5 years)	None	1 PDO	1 PI	1 F or 2 PDO's or 1 PI and 1 PDO	2 or more F's/PI's or 3 or more PDO's
ADT (current year)	< 200	200 - 299	300 - 399	400 - 750	> 750
Bridge Width (feet)	≥ 30	28	24	22	≤ 20
Bridge Length (feet)	< 50	50 - 99	100 - 149	150 - 200	> 200
Bridge Rail (type)	Aluminum Rail (1967 Standard)	Steel Box Rail (1964 Standard)	Formed Steel Beam Rail (1951 and 1957 Standards)	Steel Rail (1941 Standard) Concrete Rail (1928 Standard)	Angle Handrail (1928 Standard)

Abbreviations: PDO = Property Damage Only crash
PI = Personal Injury crash
F = Fatality crash

Upgrading Needed

< 25 Points - No Upgrading at this time

25 - 50 Points - Delineation according to Standard RE-48A

51 - 75 Points - Block out with Thrie Beam to curb edge

(If existing approach guardrail is W-Beam, W-Beam may be used)

Over 75 Points - Retrofit

APPENDIX D

Pontis Inventory Information for Sample CSAH Bridges

Table D-1. Pontis Data for Bridges WITH Approach Guardrail

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ANOKA	CSAH 26	2195	000+00.650	0.6 MI S OF JCT CSAH 24	CEDAR CREEK	1918	30.0	41.4	2	16-URB/MINOR ART	1409	2002	2	36	41.4	8
ANOKA	CSAH 24	02501	009+00.030	0.2 MI E OF JCT CSAH 28	RUM RIVER	1964	106.5	44.0	2	06-RUR/MINOR ART	9400	2003	2	44	44	7
ANOKA	CSAH 28	02502	002+00.160	0.1 MI W OF JCT CR 71	SEELYE BROOK	1961	24.8	28.1	2	06-RUR/MINOR ART	3108	2002	2	28	28.1	6
ANOKA	CSAH 13	02518	000+00.800	0.7 MI N OF JCT CSAH 22	CEDAR CREEK	1966	26.1	29.6	2	06-RUR/MINOR ART	1976	2002	2	32	29.6	6
ANOKA	CSAH 22	02519	008+00.810	0.2 MI E OF JCT CR 55	RUM RIVER	1969	78.2	30.0	2	06-RUR/MINOR ART	8586	2002	2	32	30	7
ANOKA	CSAH 2	02523	000+00.181	0.2 MI NE OF JCT CSAH 1	BNSF RR	1973	205.0	44.0	2	16-URB/MINOR ART	9103	2002	2	44	44	5
ANOKA	CSAH 7	02526	007+00.670	1.5 MI E OF JCT TH 47	RUM RIVER	1975	68.4	44.0	2	17-URB COLL	8708	2002	2	50	44	7
ANOKA	CSAH 14	02527	016+00.405	1.0 MI S OF JCT TH 35W	CHAN BETWEEN TWO LAKES	1975	31.0	48.3	2	06-RUR/MINOR ART	7201	2002	2	30	48.3	8
ANOKA	CSAH 7	02535	013+00.210	1.2 MI S OF JCT CSAH 24	SEELYE BROOK	1984	20.0	44.1	2	07-RURAL COLL	6241	2002	2	32	44.1	8
ANOKA	CSAH 9	02536	007+00.400	1.2 MI S OF JCT CSAH 22	CEDAR CREEK	1995	64.0	44.0	2	06-RUR/MINOR ART	10380	2002	2	40	44	9

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ANOKA	CSAH 78	02539	004+00.806	0.3 MI S OF JCT CSAH 16	COON CREEK	1982	64.6	54.8	2	16-URB/MINOR ART	14554	2002	2	54	54.8	8
ANOKA	CSAH 1	02541	003+00.980	1.5 MI N OF JCT TH 694	RICE CREEK	1988	51.0	34.0	4	16-URB/MINOR ART	26758	2002	2	84	68	9
ANOKA	CSAH 116	02545	002+00.026	0.4 MI E OF JCT TH 47	RUM RIVER	1990	133.4	68.0	4	16-URB/MINOR ART	17156	2002	2	68	68	8
ANOKA	CSAH 116	02546	001+00.716	0.1 MI E OF JCT TH 47	RUM RIVER OXBOW	1990	100.0	68.0	4	16-URB/MINOR ART	17156	2002	2	68	68	9
ANOKA	CSAH 22	02548	004+00.994	0.4 MI W OF JCT TH 47	FORD BROOK	1987	67.0	40.0	2	06-RUR/MINOR ART	5464	2002	2	40	40	9
ANOKA	CSAH 18	02549	002+00.571	0.2 MI N OF JCT TH 242	COON CREEK	1988	69.0	56.0	4	16-URB/MINOR ART	14479	2002	2	76	56	7
ANOKA	CSAH 11	02553	004+00.450	0.6 MI E OF JCT CSAH 78	COON CREEK	1991	42.0	56.0	4	16-URB/MINOR ART	13770	2002	2	56	56	8
ANOKA	CSAH 14	02560	001+00.049	1.0 MI W OF JCT TH 10	BNSF RR	1991	90.0	32.0	4	16-URB/MINOR ART	20076	2002	2	82	64	9
ANOKA	CSAH 116	02564	005+00.078	0.1 MI E OF JCT CSAH 16	COON CREEK	1999	27.2	33.4	5	17-URB COLL	20558	2002	2	67	78.6	8
ANOKA	CSAH 35	3310	001+00.580	0.4 MI N OF JCT CSAH 6	RICE CREEK	1920	10.0	47.0	2	17-URB COLL	10500	2003	2	44	0	6

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ANOKA	CSAH 49	4711	001+00.458	0.8 MI S OF JCT CSAH 23	CHANNEL	1927	35.0	27.0	2	16-URB/MINOR ART	14106	2002	2	36	27	7
ANOKA	CSAH 21	90734	006+00.080	2.5 MI N OF JCT CSAH 14	HARDWOOD CREEK	1960	5.0	35.0	2	07-RURAL COLL	800	2003	2	32	0	5
ANOKA	CSAH 23	90737	012+00.263	0.8 MI W OF JCT CSAH 21	RICE CREEK	1926	10.0	45.0	2	07-RURAL COLL	6100	2003	2	44	0	8
ANOKA	CSAH 1	92164	008+00.926	0.8 MI N OF JCT CSAH 11	COON CREEK	1973	14.1	48.0	5	16-URB/MINOR ART	40306	2002	2	130	106	8
ANOKA	CSAH 24	92730	017+00.590	0.5 MI E OF JCT CSAH 26	CEDAR CREEK	1970	9.5	32.0	2	07-RURAL COLL	1000	2003	2	32	0	8
ANOKA	CSAH 22	95167	012+00.146	1.9 MI E OF JCT CSAH 9	CEDAR CREEK	1983	10.2	48.0	2	06-RUR/MINOR ART	8978	2002	2	44	0	8
ANOKA	CSAH 116	96834	001+00.934	0.3 MI E OF JCT TH 47	PARK ACCESS ROAD	1990	40.0	68.0	4	16-URB/MINOR ART	17156	2002	2	68	68	8
CROW WING	CSAH 3	6518	001+00.469	2.0 MI N OF BRAINERD	MISSISSIPPI RIVER	1950	112.6	30.0	2	06-RUR/MINOR ART	8600	2001	2	44	30	8
CROW WING	CSAH 16	18501	012+00.150	1.2 MI S OF JCT CSAH 66	PINE RIVER	1963	31.1	40.3	2	07-RURAL COLL	2550	2001	2	40	40.3	9
CROW WING	CSAH 23	18502	010+00.330	1.7 MI N OF JCT CSAH 22	NOKASIPPI RIVER	1960	28.7	29.4	2	08-RUR/MINOR COLL	590	2001	2	36	29.4	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
CROW WING	CSAH 15	18503	004+00.700	2.5 MI S OF JCT CSAH 1	PINE RIVER	1971	49.6	36.0	2	07-RURAL COLL	550	2001	2	40	36	8
CROW WING	CSAH 45	18504	003+00.980	0.4 MI N OF JCT CSAH 2	NOKASIPPI RIVER	1970	31.1	40.1	2	07-RURAL COLL	930	2001	2	40	40.1	8
CROW WING	CSAH 31	18506	003+00.510	3.0 MI N OF JCT TH 210-6	RABBIT LAKE NARROWS	1974	22.0	30.8	2	08-RUR/MINOR COLL	1350	2001	2	40	30.8	8
CROW WING	CSAH 77	18508	000+00.660	2.8 MI W OF JCT TH 371	GULL RIVER	1979	81.0	44.6	2	07-RURAL COLL	4250	2001	2	48	44.6	9
CROW WING	CSAH 66	18510	000+00.980	0.9 MI N OF JCT CSAH 3	DAGGETT BROOK	1979	70.0	44.1	2	06-RUR/MINOR ART	5100	2001	2	44	44.1	9
CROW WING	CSAH 2	18512	002+00.300	2.3 MI E OF JCT TH 371	NOKASIPPI RIVER	1984	30.7	36.2	2	07-RURAL COLL	255	2001	2	36	36.2	9
CROW WING	CSAH 36	18514	007+00.820	1.5 MI W OF JCT TH 6	LITTLE PINE RIVER	1981	26.0	31.8	2	07-RURAL COLL	570	2001	2	36	31.8	9
CROW WING	CSAH 3	18517	022+00.757	0.2 MI S OF JCT CSAH 6	PINE RIVER	1985	59.5	44.0	2	06-RUR/MINOR ART	5900	2001	2	44	44	9
CROW WING	CSAH 36	18518	001+00.100	0.5 MI S OF JCT CSAH 37	PINE RIVER	1984	104.5	38.5	2	07-RURAL COLL	1100	2001	2	36	38.5	9
CROW WING	CSAH 9	18520	000+00.940	1.0 MI N OF JCT CSAH 2	NOKASIPPI RIVER	1993	32.1	36.6	2	09-RURAL LOCAL	260	2001	2	34	36.6	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
CROW WING	CSAH 2	18522	012+00.690	0.5 MI W OF JCT TH 25	DAGGETT BROOK	1996	55.8	36.0	2	07-RURAL COLL	485	2001	2	32	36	8
CROW WING	CSAH 21	18523	001+00.160	1.1 MI N OF JCT CSAH 2	NOKASIPPI RIVER	2001	69.7	36.0	2	08-RUR/MINOR COLL	530	2001	2	32	36	8
CROW WING	CSAH 11	18524	018+00.450	0.3 MI E OF JCT CSAH 19	PINE RIVER	2003	66.7	40.0	2	07-RURAL COLL	1050	2001	2	36	40	8
CROW WING	CSAH 2	92168	018+00.120	1.1 MI W OF JCT CR 132	DAGGETT BROOK	1967	9.5	36.0	2	07-RURAL COLL	1550	2001	2	36	0	8
CROW WING	CSAH 21	92547	003+00.030	0.3 MI N OF JCT CR 121	HAY CREEK	1960	12.3	32.0	2	08-RUR/MINOR COLL	940	2001	2	36	32	8
CROW WING	CSAH 8	93300	017+00.800	0.4 MI S OF JCT TH 18	GRAVE LAKE OUTLET	1977	12.8	36.0	2	07-RURAL COLL	660	2001	2	36	0	9
CROW WING	CSAH 23	L2839	001+00.930	0.9 MI N OF JCT CR 139	DAGGETT BROOK	1952	19.7	28.2	2	08-RUR/MINOR COLL	335	2001	2	32	28.2	8
CROW WING	CSAH 24	L2840	002+00.020	1.2 MI W OF JCT CSAH 8	NOKASIPPI RIVER	1962	5.0	30.0	2	09-RURAL LOCAL	345	2001	2	32	30	8
CROW WING	CSAH 1	L2863	008+00.950	0.8 MI E OF JCT CR 134	THOMPSON CREEK	1943	28.0	28.0	2	07-RURAL COLL	1400	2001	2	38	28	8
CROW WING	CSAH 3	L2865	019+00.487	0.5 MI N OF JCT CSAH 11	PELICAN BROOK	1958	12.3	40.0	2	06-RUR/MINOR ART	4350	2001	2	40	0	8

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DAKOTA	CSAH 88	4914	007+00.582	0.2 MI W OF JCT TH 52	STREAM	1930	28.3	25.0	2	07-RURAL COLL	2000	2003	2	30	25	8
DAKOTA	CSAH 9	8433	002+00.156	1.2 MI N OF JCT CSAH 80	VERMILLION RIVER	1945	9.0	30.0	2	06-RUR/MINOR ART	3300	2003	2	28	0	8
DAKOTA	CSAH 46	19502	022+00.245	0.5 MI W OF JCT CSAH 47	VERMILLION RIVER	1967	50.0	30.2	2	06-RUR/MINOR ART	4200	2003	2	44	30.2	8
DAKOTA	CSAH 46	19503	023+00.803	0.7 MI SW OF JCT TH 61	VERMILLION RIVER	1968	57.0	34.6	2	16-URB/MINOR ART	9900	2003	2	36	34.6	8
DAKOTA	CSAH 85	19504	011+00.120	0.9 MI N OF JCT CSAH 62	VERMILLION RIVER	1968	52.1	30.0	2	07-RURAL COLL	890	2003	2	48	30	8
DAKOTA	CSAH 42	19511	000+00.947	0.3 MI W OF JCT CSAH 5	CP RAIL	1971	54.0	28.0	4	14-URB/OTH PR ART	39500	2003	2	61	56	8
DAKOTA	CSAH 23	19517	011+00.320	1.5 MI S OF JCT CSAH 86	CHUB CREEK	1987	63.1	44.0	2	06-RUR/MINOR ART	3450	2003	2	44	44	8
DAKOTA	CSAH 31	19528	013+00.394	.7 MI S OF JCT CSAH 32	PARK TRAIL	1990	46.0	64.0	5	16-URB/MINOR ART	17700	2003	2	64	64	8
DAKOTA	CSAH 47	19542	000+00.840	0.1 MI S OF JCT CSAH 88	CHUB CREEK	2004	40.0	44.0	2	06-RUR/MINOR ART	3100	2003	2	40	44	9
DAKOTA	CSAH 62	96705	009+00.815	1.1 MI W OF JCT CSAH 91	DRY RUN	1990	12.0	40.0	2	07-RURAL COLL	1700	2003	2	40	0	8

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DAKOTA	CSAH 50	19J07	006+00.881	0.6 MI E OF JCT CSAH 23	E BR N FK VERMILLION R	1996	8.0	34.0	4	16-URB/MINOR ART	15000	2003	2	86	68	8
DAKOTA	CSAH 47	L3169	015+00.089	0.1 MI SW OF JCT CSAH 85	DRY RUN	1919	7.9	26.0	2	06-RUR/MINOR ART	2250	2003	2	34	26	8
DAKOTA	CSAH 47	L3170	014+00.869	0.3 MI SW OF JCT CSAH 85	DRY RUN	1919	10.0	28.0	2	06-RUR/MINOR ART	2250	2003	2	34	28	8
DAKOTA	CSAH 23	L3173	011+00.530	0.6 MI N OF JCT CSAH 78	VERMILLION RIVER	1923	10.0	43.6	2	06-RUR/MINOR ART	5700	2003	2	44	43.6	8
DAKOTA	CSAH 91	L3180	001+00.750	3.0 MI SW OF JCT TH 61	TROUT BROOK	1931	8.0	26.0	2	08-RUR/MINOR COLL	120	2003	2	30	26	7
DAKOTA	CSAH 86	L3182	009+00.810	0.9 MI E OF JCT CR 53	N BR CHUB CREEK	1940	10.0	29.4	2	06-RUR/MINOR ART	2200	2003	2	34	29.4	7
DAKOTA	CSAH 85	L3196	001+00.230	1.3 MI N OF JCT CSAH 86	PINE CREEK	1959	24.0	28.5	2	07-RURAL COLL	490	2003	2	30	28.5	8
FILLMORE	CSAH 1	5289	020+00.770	0.9 MI N OF JCT CSAH 4	STREAM	1933	41.0	24.8	2	07-RURAL COLL	1300	2001	2	28	24.8	6
FILLMORE	CSAH 1	23507	016+00.070	0.6 MI S OF JCT CSAH 4	DEER CREEK	1965	52.0	30.1	2	07-RURAL COLL	1300	2001	2	30	30.1	6
FILLMORE	CSAH 1	23508	017+00.750	1.0 MI N OF JCT CSAH 4	BEAR CREEK	1965	46.0	30.0	2	07-RURAL COLL	1300	2001	2	30	30	8

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FILLMORE	CSAH 36	23513	000+00.020	0.1 MI E OF JCT TH 16	ROOT RIVER	1969	67.2	30.0	2	09-RURAL LOCAL	365	2001	2	30	30	8
FILLMORE	CSAH 1	23514	006+00.370	0.3 MI N OF JCT CSAH 3	S BR ROOT RIVER	1970	31.1	30.7	2	07-RURAL COLL	900	2001	2	32	30.7	8
FILLMORE	CSAH 5	23516	027+00.708	0.2 MI SW OF JCT CR 102	BEAR CREEK	1971	46.0	32.0	2	07-RURAL COLL	550	2001	2	32	32	6
FILLMORE	CSAH 8	23528	002+00.050	1.0 MI SE OF JCT CSAH 4	DEER CREEK	1982	39.3	32.6	2	07-RURAL COLL	1750	2001	2	32	32.6	8
FILLMORE	CSAH 2	23535	016+00.600	0.6 MI W OF JCT TH 52	N BR ROOT RIVER	1998	59.5	39.3	2	07-RURAL COLL	760	2001	2	35	39.3	8
FILLMORE	CSAH 12	23546	020+00.700	0.3 MI W OF JCT CSAH 17	S BR ROOT RIVER	1985	95.0	44.0	2	07-RURAL COLL	760	2001	2	44	44	8
GOODHUE	CSAH 2	25501	007+00.008	0.4 MI S OF JCT CR 45	WELLS CREEK	1966	25.2	29.5	2	07-RURAL COLL	510	2003	2	36	29.5	5
GOODHUE	CSAH 18	25505	002+00.170	2.1 MI N OF JCT TH 61	VERMILLION RIVER	1968	85.8	36.0	2	06-RUR/MINOR ART	7400	2003	2	34	36	8
GOODHUE	CSAH 18	25506	002+00.720	2.6 MI N OF JCT TH 61	INDIAN SLOUGH	1968	72.3	36.0	2	06-RUR/MINOR ART	7400	2003	2	34	36	7
GOODHUE	CSAH 14	25508	004+00.220	0.1 MI S OF JCT CR 44	LITTLE CANNON RIVER	1969	52.0	30.0	2	08-RUR/MINOR COLL	245	2003	2	34	30	6

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GOODHUE	CSAH 14	25509	006+00.180	1.0 MI N OF JCT CSAH 22	LITTLE CANNON RIVER	1969	54.0	30.0	2	08-RUR/MINOR COLL	510	2003	2	32	30	7
GOODHUE	CSAH 10	25512	010+00.300	0.9 MI E OF JCT CSAH 4	N BR ZUMBRO RIVER	1971	67.1	30.0	2	07-RURAL COLL	920	2003	2	30	30	8
GOODHUE	CSAH 5	25513	014+00.060	0.5 MI W OF JCT TH 61	GILBERT CREEK	1971	44.0	36.0	2	07-RURAL COLL	2150	2003	2	32	36	7
GOODHUE	CSAH 66	25517	000+00.270	0.2 MI E OF JCT CSAH 1	HAY CREEK	1975	62.0	44.0	2	07-RURAL COLL	6700	2003	2	44	44	9
GOODHUE	CSAH 30	25520	009+00.368	1.2 MI W OF JCT TH 57	N FK ZUMBRO RIVER	1979	65.0	32.0	2	08-RUR/MINOR COLL	610	2003	2	32	32	9
GOODHUE	CSAH 27	25538	000+00.190	0.2 MI N 0F S CO LINE	N BR MID FK ZUMBRO RIVER	1982	40.0	32.0	2	08-RUR/MINOR COLL	120	2003	2	32	32	9
GOODHUE	CSAH 17	25540	002+00.970	1.9 MI E OF JCT TH 20	PINE CREEK	1986	85.0	32.0	2	08-RUR/MINOR COLL	640	2003	2	32	32	8
GOODHUE	CSAH 9	25541	005+00.430	0.3 MI W OF JCT CSAH 14	LITTLE CANNON RIVER	1981	55.0	44.0	2	07-RURAL COLL	1500	2003	2	44	44	9
GOODHUE	CSAH 24	25554	006+00.075	2.5 MI SW OF JCT TH 52	LITTLE CANNON RIVER	1983	70.0	32.0	2	08-RUR/MINOR COLL	510	2003	2	32	32	9
GOODHUE	CSAH 1	25559	022+00.447	0.2 MI E OF JCT CSAH 8	BELLE CREEK	1993	77.0	44.0	2	07-RURAL COLL	1100	2003	2	40	44	9

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GOODHUE	CSAH 1	25562	007+00.290	0.8 MI N OF JCT TH 60	N FK ZUMBRO RIVER	1993	55.2	40.0	2	07-RURAL COLL	710	2003	2	36	40	9
GOODHUE	CSAH 30	25564	008+00.910	1.5 MI W OF JCT TH 57	STREAM	1987	31.7	32.1	2	08-RUR/MINOR COLL	420	2003	2	32	32.1	9
GOODHUE	CSAH 5	25566	005+00.180	0.4 MI E OF JCT CSAH 2	WELLS CREEK	1992	68.4	36.0	2	07-RURAL COLL	650	2003	2	36	36	9
GOODHUE	CSAH 21	25582	003+00.400	0.4 MI S OF JCT TH 61	BULLARD CREEK	1998	37.7	43.0	2	08-RUR/MINOR COLL	1000	2003	2	39	43	9
LYON	CSAH 13	42512	019+00.470	2.3 MI N OF JCT TH 19	S BR YELLOW MEDICINE R	1967	26.0	30.0	2	08-RUR/MINOR COLL	145	2001	2	36	30	8
LYON	CSAH 13	42514	017+00.460	0.2 MI N OF JCT TH 19	S BR YELLOW MEDICINE R	1967	26.0	30.0	2	08-RUR/MINOR COLL	145	2001	2	36	30	8
LYON	CSAH 33	42539	002+00.825	0.6 MI E OF JCT TH 59	BNSF RR	1983	61.0	44.0	2	07-RURAL COLL	3950	2001	2	44	44	9
LYON	CSAH 33	42541	003+00.475	1.2 MI E OF JCT TH 59	REDWOOD RIVER	1983	50.0	44.0	2	07-RURAL COLL	3950	2001	2	48	44	9
LYON	CSAH 2	42557	020+00.110	0.9 mi E of jct CSAH 9	Cottonwood River	2002	101.7	40.0	2	07-RURAL COLL	244	2001	2	36	40	8
MOWER	CSAH 2	736	004+00.040	0.1 MI E OF JCT CSAH 25	STREAM	1939	28.1	29.0	2	07-RURAL COLL	730	1996	2	28	29	8

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MOWER	CSAH 25	2227	003+00.830	1.8 MI S OF JCT CSAH 2	STREAM	1958	23.0	27.5	2	08-RUR/MINOR COLL	800	1996	2	26	27.5	8
MOWER	CSAH 4	2534	021+00.130	1.6 MI E OF JCT CSAH 7	STREAM	1917	24.0	22.8	2	08-RUR/MINOR COLL	75	1996	2	35	22.8	8
MOWER	CSAH 8	4569	010+00.570	0.6 MI N OF JCT CSAH 13	DEER CREEK	1926	47.0	23.5	2	07-RURAL COLL	315	1996	2	30	23.5	8
MOWER	CSAH 29	5368	003+00.700	0.3 MI S OF OAKLAND AVE	CEDAR RIVER	1933	84.0	30.0	2	16-URB/MINOR ART	2950	1996	2	40	30	5
MOWER	CSAH 5	7016	002+00.250	0.1 MI E OF JCT TH 105	CEDAR RIVER	1951	85.0	24.1	2	07-RURAL COLL	210	1996	2	32	24.1	8
MOWER	CSAH 23	7048	000+00.960	0.9 MI N OF JCT CSAH 28	TURTLE CREEK	1955	60.0	28.0	2	16-URB/MINOR ART	2150	1996	2	30	28	8
MOWER	CSAH 4	7050	011+00.170	0.8 MI W OF JCT CSAH 19	ROSE CREEK	1957	60.1	24.0	2	07-RURAL COLL	610	1996	2	32	24	8
MOWER	CSAH 6	7091	002+00.350	0.3 MI E OF JCT TH 105	CEDAR RIVER	1953	85.0	24.0	2	07-RURAL COLL	640	1996	2	36	24	8
MOWER	CSAH 14	7148	000+00.200	0.2 MI N OF JCT TH 56	UPPER IOWA RIVER	1955	71.0	24.0	2	07-RURAL COLL	1200	1996	2	29	24	8
MOWER	CSAH 28	7232	003+00.680	0.2 MI W OF JCT CSAH 29	CEDAR RIVER	1959	80.0	28.0	2	17-URB COLL	1300	1996	2	30	28	8

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MOWER	CSAH 16	50502	007+00.200	0.1 MI N OF JCT CSAH 2	ROBERTS CREEK	1960	30.0	27.3	2	07-RURAL COLL	400	1996	2	26	27.3	8
MOWER	CSAH 16	50503	000+00.900	0.9 MI S OF JCT CSAH 25	WOLF CREEK	1960	28.5	40.0	2	16-URB/MINOR ART	2100	1996	2	45	40	8
MOWER	CSAH 1	50504	002+00.360	0.8 MI E OF JCT TH 218	CEDAR RIVER	1961	31.2	27.2	2	07-RURAL COLL	410	1996	2	30	27.2	8
MOWER	CSAH 25	50507	008+00.750	1.9 MI S OF JCT CSAH 1	RED CEDAR RIVER	1963	31.5	27.0	2	08-RUR/MINOR COLL	230	1996	2	28	27	5
MOWER	CSAH 7	50513	023+00.370	2.5 MI S OF JCT CSAH 1	N BR ROOT RIVER	1968	25.0	31.2	2	07-RURAL COLL	270	1996	2	28	31.2	8
MOWER	CSAH 7	50514	022+00.530	2.1 MI N OF JCT CSAH 2	STREAM	1967	31.0	31.0	2	07-RURAL COLL	270	1996	2	29	31	8
MOWER	CSAH 13	50515	000+00.380	0.2 MI E OF JCT CR 59	ROSE CREEK	1968	25.0	30.7	2	07-RURAL COLL	330	1996	2	27	30.7	8
MOWER	CSAH 14	50516	003+00.980	0.8 MI N OF JCT CSAH 11	LITTLE IOWA RIVER	1968	25.0	30.7	2	07-RURAL COLL	1050	1996	2	32	30.7	8
MOWER	CSAH 25	50517	000+00.110	0.1 MI N OF JCT CSAH 16	CEDAR RIVER	1968	61.0	30.0	2	08-RUR/MINOR COLL	750	1996	2	31	30	8
MOWER	CSAH 7	50519	004+00.350	0.3 MI E OF JCT CSAH 5	LITTLE CEDAR RIVER	1968	31.2	29.4	2	07-RURAL COLL	700	1996	2	37	29.4	8

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MOWER	CSAH 8	50520	014+00.140	0.1 MI N OF JCT CSAH 2	N FK BEAR CREEK	1970	25.1	29.3	2	07-RURAL COLL	500	1996	2	29	29.3	8
MOWER	CSAH 2	50524	004+00.590	0.5 MI E OF JCT CSAH 25	CEDAR RIVER	1971	60.0	32.0	2	07-RURAL COLL	730	1996	2	28	32	8
MOWER	CSAH 4	50528	006+00.970	1.5 MI E OF JCT TH 218	ROSE CREEK	1973	31.1	37.0	2	07-RURAL COLL	610	1996	2	32	37	8
MOWER	CSAH 8	50576	013+00.300	1.3 MI N OF JCT TH 16	S FK BEAR CREEK	1995	101.5	40.0	2	07-RURAL COLL	770	1996	2	36	40	9
MOWER	CSAH 7	89215	006+00.870	0.4 MI S OF JCT TH 56	STREAM	1958	28.8	40.0	2	07-RURAL COLL	1150	1996	2	31	40	8
MOWER	CSAH 20	89228	016+00.860	0.6 MI W OF JCT CSAH 7	STREAM	1934	30.2	24.1	2	09-RURAL LOCAL	180	1996	2	34	24.1	8
MOWER	CSAH 21	92138	000+00.170	0.2 MI N OF JCT CSAH 28	DITCH	1967	23.1	30.5	2	09-RURAL LOCAL	200	1996	2	26	30.5	8
MOWER	CSAH 9	93079	005+00.960	0.1 MI S OF JCT TH 56	N BR UPPER IOWA RIVER	1974	23.0	33.2	2	08-RUR/MINOR COLL	65	1996	2	35	33.2	8
OLMSTED	CSAH 19	5877	002+00.980	2.3 MI S OF JCT TH 52	N BR ROOT RIVER	1939	46.6	24.0	2	08-RUR/MINOR COLL	495	2002	2	36	24	5
OLMSTED	CSAH 1	7092	011+00.360	0.2 MI S OF JCT CR 146	WILLOW CREEK	1952	45.0	52.0	4	16-URB/MINOR ART	8200	2002	2	68	52	8

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OLMSTED	CSAH 3	7212	033+00.050	0.5 MI N OF JCT CSAH 5	MID FK ZUMBRO RIVER	1959	65.0	30.0	2	07-RURAL COLL	2200	2002	2	32	30	6
OLMSTED	CSAH 14	55506	003+00.770	1.3 MI E OF JCT CR 105	S BR MID FK ZUMBRO RIVER	1963	66.6	30.4	2	08-RUR/MINOR COLL	660	2002	2	36	30.4	8
OLMSTED	CSAH 8	55512	001+00.750	0.7 MI N OF JCT CSAH 6	N BR ROOT RIVER	1966	68.0	30.0	2	08-RUR/MINOR COLL	1000	2002	2	36	30	8
OLMSTED	CSAH 3	55515	013+00.680	0.5 MI S OF JCT CSAH 25	SALEM CREEK	1967	51.7	32.0	2	07-RURAL COLL	1150	2002	2	40	32	8
OLMSTED	CSAH 22	55519	011+00.290	0.7 MI W OF JCT TH 63	S FK ZUMBRO RIVER	1969	86.5	54.4	4	14-URB/OTH PR ART	25500	2002	2	68	54.4	8
OLMSTED	CSAH 12	55520	009+00.624	2.6 MI W OF JCT TH 63	ZUMBRO RIVER	1975	135.0	44.0	2	06-RUR/MINOR ART	1950	2002	2	44	44	8
OLMSTED	CSAH 7	55521	003+00.710	0.4 MI N OF JCT TH 52	MILL CREEK	1971	31.0	43.3	2	06-RUR/MINOR ART	940	2002	2	44	43.3	8
OLMSTED	CSAH 5	55527	007+00.460	0.8 MI NW OF JCT CSAH 4	S BR MID FK ZUMBRO RIVER	1977	100.0	44.0	2	07-RURAL COLL	2300	2002	2	40	44	8
OLMSTED	CSAH 14	55530	011+00.620	0.8 MI W OF JCT TH 63	S FK ZUMBRO RIVER	1979	115.0	44.0	2	07-RURAL COLL	5200	2002	2	44	44	9
OLMSTED	CSAH 22 SB	55548	014+00.950	0.5 MI N OF JCT CSAH 9	SILVER CREEK	1987	32.0	40.0	2	14-URB/OTH PR ART	6100	2002	1	40	40	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
OLMSTED	CSAH 3	55554	003+00.370	0.8 MI N OF JCT CSAH 6	N BR ROOT RIVER	1996	43.2	36.0	2	08-RUR/MINOR COLL	265	2002	2	32	36	9
OLMSTED	CSAH 22 WB	55559	014+00.950	0.5 MI N OF JCT CSAH 9	SILVER CREEK	1995	32.0	42.0	2	14-URB/OTH PR ART	6100	2002	1	35	42	9
OLMSTED	CSAH 10	95764	010+00.929	0.1 MI S OF JCT TH 14	S FK WHITEWATER RIVER	1986	40.3	40.0	2	07-RURAL COLL	1550	2002	2	40	40	8
ROCK	CSAH 17	6787	006+00.490	1.0 MI S OF JCT TH 90	BEAVER CREEK	1955	32.5	30.3	2	07-RURAL COLL	560	2002	2	32	30.3	8
ROCK	CSAH 4	67524	018+00.805	0.7 MI W OF JCT CSAH 3	ELK CREEK	1984	33.4	41.6	2	07-RURAL COLL	1450	2002	2	40	41.6	8
ROCK	CSAH 5	L2033	007+00.950	1.9 MI E OF JCT CSAH 6	BEAVER CREEK	1956	60.0	24.0	2	07-RURAL COLL	350	2002	2	34	24	9
WATON-WAN	CSAH 3	1383	022+00.749	2.3 MI E OF JCT CSAH16	JUD DITCH # 13	1914	15.6	25.9	2	07-RURAL COLL	1300	2001	2	42	25.9	8
WATON-WAN	CSAH 57	8259	000+00.441	0.1 MI E OF JCT CR 114	ST JAMES LAKE	1932	10.0	43.0	2	07-RURAL COLL	2700	2001	2	43	0	8
WATON-WAN	CSAH 3	83504	025+00.199	1.7 MI W OF JCT TH15	ELM CREEK	1963	25.2	29.3	2	06-RUR/MINOR ART	1300	2001	2	42	29.3	8
WATON-WAN	CSAH 27	83506	016+00.420	1.0 MI N OF JCT CSAH3	N FK WATONWAN RIVER	1967	31.1	32.5	2	06-RUR/MINOR ART	1650	2001	2	40	32.5	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
WATON-WAN	CSAH 12	83513	003+00.450	1.4 MI N OF JCT CSAH 10	S FK WATONWAN RIVER	1978	36.4	32.0	2	07-RURAL COLL	255	2001	2	26	32	8
WATON-WAN	CSAH 27	83539	003+00.130	1.0 MI S OF JCT CSAH 10	S FK WATONWAN RIVER	1996	100.0	44.0	2	07-RURAL COLL	1200	2001	2	40	44	9
WATON-WAN	CSAH 18	90340	003+00.000	0.9 MI N OF JCT CR116	WATONWAN RIVER	1920	10.0	26.0	2	08-RUR/MINOR COLL	40	2001	2	38	26	8
WATON-WAN	CSAH 19	90344	002+00.800	0.9 MI N OF JCT CSAH7	S FK WATONWAN RIVER	1918	38.0	26.4	2	08-RUR/MINOR COLL	290	2001	2	32	26.4	7
WATON-WAN	CSAH 19	90343	006+00.760	0.4 MI N OF JCT CR119	CREEK	1923	19.9	26.5	2	08-RUR/MINOR COLL	135	2001	2	35	26.5	8

Table D-2. Pontis Data for Bridges WITHOUT Approach Guardrail

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ANOKA	CSAH 51	02520	003+00.680	1.0 MI S OF JCT TH 242	SAND CREEK	1966	25.8	52.5	2	16-URB/MINOR ART	16500	2003	2	52	52.5	8
ANOKA	CSAH 30	02531	000+00.140	0.1 MI E OF JCT TH 47	RUM RIVER	1980	105.2	44.0	2	19-URBAN LOCAL	7970	2002	2	44	44	8
ANOKA	CSAH 78	95884	001+00.780	0.3 MI N OF JCT TH 10	COON CREEK	1983	40.3	52.0	4	16-URB/MINOR ART	26970	2002	2	52	52	8
CROW WING	CSAH 1	6519	015+00.110	0.4 MI W OF JCT CSAH 3	DAGGETT BROOK	1952	37.6	24.0	2	06-RUR/MINOR ART	2050	2001	2	36	24	8
DAKOTA	CSAH 54	2951	002+00.640	2.9 MI SE OF JCT CR 91	DRY RUN	1918	11.2	32.0	2	07-RURAL COLL	4200	2003	2	32	32	8
DAKOTA	CSAH 91	7271	001+00.920	2.8 MI SW OF JCT TH 61	STREAM	1949	26.7	29.5	2	08-RUR/MINOR COLL	120	2003	2	32	29.5	_
DAKOTA	CSAH 31	19512	002+00.076	0.6 MI N OF JCT CSAH 74	VERMILLION RIVER	1974	50.0	52.0	2	17-URB COLL	9900	2003	2	48	52	8
DAKOTA	CSAH 68	19529	002+00.000	0.3 MI NE OF JCT CSAH 54	VERMILLION RIVER	1996	76.0	44.0	2	06-RUR/MINOR ART	5200	2003	2	40	44	8
DAKOTA	CSAH 50	19532	009+00.472	0.3 MI E OF JCT CSAH 31	VERMILLION RIVER	1996	38.0	48.0	3	16-URB/MINOR ART	13500	2003	2	48	48	8
DAKOTA	CSAH 66	19541	006+00.580	0.1 MI W OF JCT TH 52	VERMILLION RIVER	2004	83.3	44.0	2	06-RUR/MINOR ART	1850	2003	2	40	44	9

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
DAKOTA	CSAH 26	97556	006+00.809	0.2 MI W OF JCT CSAH 75	PED WALK	1992	20.0	64.0	4	16-URB/MINOR ART	10400	2003	2	64	64	8
FILLMORE	CSAH 12	376	018+00.420	0.6 MI W OF JCT CSAH 14	STREAM	1943	25.5	23.0	2	08-RUR/MINOR COLL	165	2001	2	26	23	8
FILLMORE	CSAH 12	449	016+00.970	0.8 MI E OF JCT CR 118	STREAM	1937	40.5	26.4	2	08-RUR/MINOR COLL	165	2001	2	30	26.4	8
FILLMORE	CSAH 2	2915	003+00.270	1.5 MI W OF JCT CSAH 1	KEDRON BROOK	1953	26.5	24.0	2	07-RURAL COLL	220	2001	2	30	24	8
FILLMORE	CSAH 6	3309	000+00.900	0.7 MI SE OF JCT TH 52	RICE CREEK	1941	31.3	23.1	2	09-RURAL LOCAL	110	2001	2	30	23.1	8
FILLMORE	CSAH 40	4026	002+00.020	2.0 MI E OF JCT TH 52	STREAM	1923	24.0	22.2	2	08-RUR/MINOR COLL	125	2001	2	26	22.2	8
FILLMORE	CSAH 24	4408	001+00.460	0.7 MI W OF JCT CSAH 28	S BR S FK ROOT RIVER	1925	34.3	23.6	2	08-RUR/MINOR COLL	275	2001	2	32	23.6	8
FILLMORE	CSAH 40	6081	001+00.430	1.5 MI E OF JCT TH 52	LYNCH CREEK	1930	32.7	18.5	2	08-RUR/MINOR COLL	125	2001	2	26	18.5	3
FILLMORE	CSAH 40	6082	000+00.350	0.3 MI E OF JCT TH 52	STREAM	1923	23.0	24.2	2	08-RUR/MINOR COLL	175	2001	2	26	24.2	3
FILLMORE	CSAH 15	7188	010+00.600	1.2 MI N OF JCT CSAH 22	WILLOW CREEK	1958	40.0	26.0	2	07-RURAL COLL	245	2001	2	30	26	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 2	7253	003+00.400	1.3 MI W OF JCT CSAH 1	KEDRON BROOK	1958	41.0	24.2	2	07-RURAL COLL	220	2001	2	30	24.2	8
FILLMORE	CSAH 27	7280	001+00.800	0.5 MI W OF JCT TH 43	STREAM	1959	24.5	26.5	2	08-RUR/MINOR COLL	290	2001	2	28	26.5	8
FILLMORE	CSAH 1	7950	000+00.780	0.2 MI W OF JCT CR 109	BEAVER CREEK	1939	23.0	35.8	2	07-RURAL COLL	850	2001	2	32	35.8	8
FILLMORE	CSAH 4	7955	001+00.680	1.6 MI E OF JCT CSAH 1	KEDRON BROOK	1936	22.5	19.0	2	07-RURAL COLL	120	2001	2	28	19	8
FILLMORE	CSAH 5	7959	018+00.998	0.3 MI N OF JCT CSAH 8	CARTERS CREEK	1920	30.3	23.5	2	07-RURAL COLL	680	2001	2	28	23.5	4
FILLMORE	CSAH 7	7963	006+00.390	0.7 MI S OF JCT CSAH 5	SHADY CREEK	1904	29.0	25.0	2	09-RURAL LOCAL	230	2001	2	26	25	8
FILLMORE	CSAH 7	7964	005+00.720	1.3 MI S OF JCT CSAH 5	STREAM	1939	21.3	22.1	2	09-RURAL LOCAL	230	2001	2	26	22.1	8
FILLMORE	CSAH 11	7973	002+00.890	1.6 MI N OF JCT TH 16	WATSON CREEK	1939	40.0	23.0	2	08-RUR/MINOR COLL	135	2001	2	30	23	8
FILLMORE	CSAH 15	7979	009+00.400	0.1 MI N OF JCT CSAH 22	STREAM	1904	16.8	16.0	1	07-RURAL COLL	245	2001	2	30	16	8
FILLMORE	CSAH 15	7980	007+00.910	0.5 MI E OF JCT CR 110	STREAM	1904	16.5	18.5	1	07-RURAL COLL	110	2001	2	28	18.5	3

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 15	7983	000+00.850	0.9 MI N OF JCT CSAH 30	STREAM	1929	25.0	28.4	2	07-RURAL COLL	385	2001	2	28	28.4	8
FILLMORE	CSAH 16	7984	007+00.730	1.3 MI E OF JCT CR 111	DITCH	1941	11.0	26.4	2	09-RURAL LOCAL	140	2001	2	28	26.4	8
FILLMORE	CSAH 16	7985	001+00.360	1.3 MI E OF JCT CSAH 17	CAMP CREEK	1936	24.5	19.0	2	09-RURAL LOCAL	275	2001	2	28	19	8
FILLMORE	CSAH 16	7986	002+00.230	1.3 MI W OF JCT TH 52	STREAM	1940	31.0	23.1	2	09-RURAL LOCAL	275	2001	2	28	23.1	8
FILLMORE	CSAH 21	7992	021+00.140	1.7 MI NW OF JCT CSAH 8	STREAM	1953	22.2	23.1	2	08-RUR/MINOR COLL	120	2001	2	30	23.1	8
FILLMORE	CSAH 23	9916	015+00.230	0.9 MI S OF JCT TH 16	WHALAN CREEK	1904	30.4	13.5	1	08-RUR/MINOR COLL	65	2001	2	26	13.5	3
FILLMORE	CSAH 23	9917	013+00.420	2.8 MI S OF JCT TH 16	WHALAN CREEK	1953	22.0	23.0	2	08-RUR/MINOR COLL	65	2001	2	26	23	8
FILLMORE	CSAH 23	9918	012+00.560	3.4 MI S OF JCT TH 16	WHALAN CREEK	1947	22.0	24.0	2	08-RUR/MINOR COLL	65	2001	2	26	24	8
FILLMORE	CSAH 23	9922	002+00.980	0.9 MI S OF JCT CSAH 24	WEISEL CREEK	1951	29.0	23.1	2	08-RUR/MINOR COLL	265	2001	2	30	23.1	6
FILLMORE	CSAH 25	9923	013+00.660	1.6 MI N OF JCT TH 30	PINE CREEK	1936	40.8	19.0	2	08-RUR/MINOR COLL	255	2001	2	32	19	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 26	9929	001+00.980	0.3 MI E OF JCT CR 109	STREAM	1952	31.4	23.0	2	09-RURAL LOCAL	85	2001	2	24	23	8
FILLMORE	CSAH 26	9931	003+00.240	1.5 MI W OF JCT TH 63	STREAM	1936	36.3	21.2	2	09-RURAL LOCAL	85	2001	2	24	21.2	8
FILLMORE	CSAH 29	9938	002+00.680	1.2 MI E OF JCT TH 43	STREAM	1940	21.5	25.2	2	08-RUR/MINOR COLL	50	2001	2	28	25.2	8
FILLMORE	CSAH 29	9939	003+00.020	1.6 MI E OF JCT TH 43	STREAM	1949	28.3	23.5	2	08-RUR/MINOR COLL	50	2001	2	28	23.5	8
FILLMORE	CSAH 29	9940	003+00.480	1.9 MI E OF JCT TH 43	RICEFORD CREEK	1940	31.3	22.7	2	08-RUR/MINOR COLL	50	2001	2	28	22.7	6
FILLMORE	CSAH 29	9942	004+00.320	2.8 MI E OF JCT TH 43	RICEFORD CREEK	1950	31.9	23.2	2	08-RUR/MINOR COLL	50	2001	2	28	23.2	8
FILLMORE	CSAH 30	9945	013+00.160	1.1 MI W OF JCT TH 139	STREAM	1908	22.3	27.7	2	08-RUR/MINOR COLL	155	2001	2	30	27.7	8
FILLMORE	CSAH 30	9946	014+00.410	0.1 MI E OF JCT TH 139	STREAM	1947	31.0	23.0	2	08-RUR/MINOR COLL	85	2001	2	30	23	8
FILLMORE	CSAH 5	23501	020+00.708	0.7 MI N OF JCT CSAH 8	ROOT RIVER	1961	92.8	28.0	2	07-RURAL COLL	680	2001	2	32	28	8
FILLMORE	CSAH 1	23502	011+00.770	0.1 MI W OF JCT TH 63	SPRING VALLEY CREEK	1961	40.0	60.0	2	07-RURAL COLL	1850	2001	2	60	60	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 25	23503	007+00.580	0.1 MI W OF JCT TH 16	ROOT RIVER	1963	109.5	30.0	2	08-RUR/MINOR COLL	990	2001	2	42	30	8
FILLMORE	CSAH 23	23505	006+00.740	1.0 MI N OF JCT CSAH 18	S BR S FK ROOT RIVER	1963	25.0	29.7	2	08-RUR/MINOR COLL	300	2001	2	28	29.7	8
FILLMORE	CSAH 8	23506	033+00.500	0.1 MI W OF JCT TH 250	S BR ROOT RIVER	1964	78.0	30.0	2	07-RURAL COLL	1250	2001	2	30	30	8
FILLMORE	CSAH 5	23509	029+00.518	1.1 MI S OF JCT TH 52	N BR ROOT RIVER	1966	72.0	30.0	2	07-RURAL COLL	1000	2001	2	36	30	8
FILLMORE	CSAH 17	23510	009+00.170	0.3 MI S OF JCT CSAH 12	S BR ROOT RIVER	1967	65.9	30.0	2	08-RUR/MINOR COLL	1800	2001	2	30	30	8
FILLMORE	CSAH 27	23511	004+00.660	0.2 MI E OF JCT TH 43	RUSH CREEK	1967	68.1	30.3	2	08-RUR/MINOR COLL	2100	2001	2	35	30.3	8
FILLMORE	CSAH 12	23512	019+00.780	0.3 MI W OF JCT CSAH 15	WILLOW CREEK	1970	45.0	36.0	2	07-RURAL COLL	760	2001	2	36	36	8
FILLMORE	CSAH 34	23515	001+00.436	0.1 MI E OF JCT TH 44	RICEFORD CREEK	1971	65.0	44.0	2	09-RURAL LOCAL	1200	2001	2	44	44	8
FILLMORE	CSAH 29	23518	003+00.710	4.0 MI N OF JCT TH 44	RICEFORD CREEK	1974	31.7	32.1	2	08-RUR/MINOR COLL	50	2001	2	32	32.1	8
FILLMORE	CSAH 26	23519	002+00.130	2.7 MI W OF JCT TH 63	BEAVER CREEK	1974	18.0	32.1	2	09-RURAL LOCAL	15	2001	2	32	32.1	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 7	23520	006+00.780	0.35 MI S OF JCT CSAH 5	MID BR ROOT RIVER	1975	42.0	32.1	2	09-RURAL LOCAL	230	2001	2	32	32.1	8
FILLMORE	CSAH 21	23521	023+00.350	0.9 MI N OF JCT CSAH 6	N BR ROOT RIVER	1977	95.0	32.0	2	08-RUR/MINOR COLL	120	2001	2	32	32	8
FILLMORE	CSAH 5	23522	010+00.798	0.4 MI S OF JCT CSAH 12	S BR ROOT RIVER	1977	60.0	32.0	2	07-RURAL COLL	430	2001	2	32	32	8
FILLMORE	CSAH 27	23527	000+00.820	1.4 MI W OF JCT TH 43	STREAM	1982	81.5	32.6	2	08-RUR/MINOR COLL	290	2001	2	32	32.6	8
FILLMORE	CSAH 8	23529	012+00.490	2.2 mi NW of jct CSAH 5	Mid Br Root River	2001	72.2	35.4	2	08-RUR/MINOR COLL	50	2001	2	24	35.4	8
FILLMORE	CSAH 8	23530	017+00.260	0.1 MI E OF JCT CSAH 5	STREAM	1983	42.9	32.6	2	08-RUR/MINOR COLL	435	2001	2	40	32.6	8
FILLMORE	CSAH 13	23533	000+00.550	0.5 MI E OF JCT TH 43	S FK ROOT RIVER	1985	57.2	32.6	2	08-RUR/MINOR COLL	50	2001	2	32	32.6	8
FILLMORE	CSAH 12	23538	016+00.450	0.4 MI S OF JCT CSAH 11	S BR ROOT RIVER	1981	47.3	32.6	2	08-RUR/MINOR COLL	165	2001	2	32	32.6	8
FILLMORE	CSAH 38	23539	005+00.910	0.3 MI S OF JCT CSAH 4	BEAR CREEK	1986	53.0	32.0	2	08-RUR/MINOR COLL	105	2001	2	28	32	8
FILLMORE	CSAH 1	23540	011+00.400	0.4 MI W OF JCT TH 63	SPRING VALLEY CREEK	1981	80.0	32.6	2	07-RURAL COLL	1050	2001	2	32	32.6	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 11	23541	012+00.180	1.6 MI S OF JCT TH 30	N BR ROOT RIVER	1980	130.0	32.0	2	07-RURAL COLL	310	2001	2	32	32	8
FILLMORE	CSAH 2	23545	016+00.810	0.4 MI SW OF JCT TH 52	MILL CREEK	1983	50.0	40.6	2	07-RURAL COLL	1400	2001	2	40	40.6	8
FILLMORE	CSAH 12	23547	035+00.250	2.1 MI W OF JCT TH 43	S FK ROOT RIVER	1988	85.0	32.0	2	07-RURAL COLL	490	2001	2	32	32	8
FILLMORE	CSAH 28	23550	001+00.540	0.5 MI S OF JCT TH 44	RICEFORD CREEK	1994	40.0	44.0	2	07-RURAL COLL	890	2001	2	40	44	8
FILLMORE	CSAH 13	23554	003+00.190	3.0 MI E OF JCT TH 43	S FK ROOT RIVER	1997	60.0	32.1	2	08-RUR/MINOR COLL	50	2001	2	28	32.1	9
FILLMORE	CSAH 12	23557	021+00.950	0.1 MI W OF JCT TH 52	CAMP CREEK	1997	87.2	43.3	2	07-RURAL COLL	2050	2001	2	40	43.3	8
FILLMORE	CSAH 12	23558	021+00.280	0.3 MI E OF JCT CSAH 17	S BR ROOT RIVER	1996	93.6	43.3	2	07-RURAL COLL	2050	2001	2	44	43.3	8
FILLMORE	CSAH 27	23559	000+00.370	1.8 MI W OF JCT TH 43	RUSH CREEK	1996	45.0	36.0	2	09-RURAL LOCAL	290	2001	2	32	36	8
FILLMORE	CSAH 18	23561	005+00.950	1.3 mi W of jct TH 43	Weisel Creek	2001	83.0	36.0	2	09-RURAL LOCAL	92	2001	2	32	36	8
FILLMORE	CSAH 8	23562	011+00.860	2.8 mi NW of jct CSAH 5	Deer Creek	2001	81.4	36.0	2	08-RUR/MINOR COLL	50	2001	2	32	36	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
FILLMORE	CSAH 38	23567	002+00.990	3.2 MI NE OF JCT CSAH 1	DEER CREEK	2003	50.0	32.0	2	08-RUR/MINOR COLL	105	2001	2	28	32	9
FILLMORE	CSAH 11	88879	000+00.140	0.1 MI N OF JCT CSAH 12	STREAM	1940	20.0	23.0	2	08-RUR/MINOR COLL	225	2001	2	28	23	8
FILLMORE	CSAH 21	88903	021+00.950	0.7 MI S OF JCT CSAH 6	STREAM	1939	21.0	20.7	2	08-RUR/MINOR COLL	120	2001	2	28	20.7	8
FILLMORE	CSAH 23	93038	004+00.200	0.3 MI N OF JCT CSAH 24	STREAM	1955	29.3	24.3	2	08-RUR/MINOR COLL	255	2001	2	28	24.3	6
GOODHUE	CSAH 62	757	000+00.580	0.1 MI S OF JCT CSAH 11	ZUMBRO RIVER	1913	45.1	34.0	2	07-RURAL COLL	8600	2003	2	80	34	6
GOODHUE	CSAH 2	2103	010+00.435	0.2 MI N OF JCT CSAH 5	STREAM	1960	58.9	25.0	2	07-RURAL COLL	820	2003	2	30	25	6
GOODHUE	CSAH 2	25504	007+00.730	0.2 MI N OF JCT CR 45	WELLS CREEK	1967	41.3	30.1	2	07-RURAL COLL	510	2003	2	36	30.1	7
GOODHUE	CSAH 8	25516	007+00.870	0.25 MI N OF JCT CSAH 9	BELLE CREEK	1973	31.0	34.1	2	08-RUR/MINOR COLL	395	2003	2	42	34.1	8
GOODHUE	CSAH 6	25518	005+00.300	7.0 MI N OF ZUMBROTA	DRY RUN	1974	31.0	34.5	2	07-RURAL COLL	1450	2003	2	32	34.5	8
GOODHUE	CSAH 4	25521	004+00.870	0.9 MI S OF JCT CR 42	TROUT BROOK	1976	45.0	32.0	2	08-RUR/MINOR COLL	350	2003	2	42	32	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
GOODHUE	CSAH 7	25522	020+00.480	2.5 MI S OF JCT TH 61	CANNON RIVER	1979	94.0	36.0	2	07-RURAL COLL	455	2003	2	36	36	8
GOODHUE	CSAH 7	25530	016+00.910	2.8 MI N OF JCT TH 19	STREAM	1986	26.0	32.0	2	07-RURAL COLL	320	2003	2	32	32	9
GOODHUE	CSAH 7	25531	017+00.160	3.0 MI N OF JCT CSAH 19	BELLE CREEK	1979	70.0	32.0	2	07-RURAL COLL	320	2003	2	32	32	9
GOODHUE	CSAH 6	25532	005+00.990	1.9 MI S OF JCT CSAH 9	STREAM	1979	50.0	32.0	2	07-RURAL COLL	1450	2003	2	32	32	9
GOODHUE	CSAH 14	25534	011+00.630	0.4 MI S OF JCT TH 52	BUTLER CREEK	1979	32.0	36.6	2	07-RURAL COLL	1000	2003	2	36	36.6	9
GOODHUE	CSAH 2	25535	017+00.944	0.4 MI N OF JCT TH 61	WELLS CREEK	1980	75.0	36.0	2	07-RURAL COLL	450	2003	2	36	36	9
GOODHUE	CSAH 30	25563	010+00.080	0.1 MI W OF JCT TH 57	SHINGLE CREEK	1987	31.7	32.2	2	08-RUR/MINOR COLL	610	2003	2	32	32.2	9
GOODHUE	CSAH 3	25575	002+00.980	0.8 MI W OF JCT CSAH 2	WELLS CREEK	1995	122.0	40.0	2	07-RURAL COLL	510	2003	2	36	40	9
LYON	CSAH 25	5034	000+00.740	2.1 MI SW OF JCT CSAH 5	REDWOOD RIVER	1931	73.0	27.0	2	09-RURAL LOCAL	35	2001	2	24	27	9
LYON	CSAH 32	5524	000+00.471	0.1 MI N OF JCT TH 23	BNSF RR	1936	36.0	39.3	2	09-RURAL LOCAL	820	2001	2	32	39.3	9

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
LYON	CSAH 5	7209	020+00.900	0.6 MI S OF JCT CR 76	THREE MILE CREEK	1958	23.0	28.0	2	07-RURAL COLL	400	2001	2	26	28	8
LYON	CSAH 8	7210	011+00.380	0.9 MI W OF JCT CR 65	THREE MILE CREEK	1958	25.0	28.0	2	07-RURAL COLL	340	2001	2	26	28	8
LYON	CSAH 3	7211	012+00.870	1.5 MI N OF JCT CSAH 26	N BR YELLOW MEDICINE R	1958	25.0	28.0	2	08-RUR/MINOR COLL	420	2001	2	28	28	8
LYON	CSAH 10	42502	014+00.820	0.8 MI W OF JCT TH 14	YELLOW MEDICINE RIVER	1960	26.0	28.6	2	07-RURAL COLL	215	2001	2	32	28.6	8
LYON	CSAH 8	42503	020+00.170	1.5 MI W OF JCT CSAH 9	THREE MILE CREEK	1962	26.3	28.8	2	08-RUR/MINOR COLL	140	2001	2	30	28.8	8
LYON	CSAH 10	42505	004+00.700	0.4 MI W OF JCT CSAH 3	STREAM	1963	24.0	28.5	2	08-RUR/MINOR COLL	380	2001	2	28	28.5	8
LYON	CSAH 11	42507	007+00.980	0.6 MI S OF JCT CSAH 2	BIG COTTONWOOD RIVER	1964	24.0	30.0	2	07-RURAL COLL	590	2001	2	38	30	8
LYON	CSAH 7	42510	001+00.530	1.5 MI S OF JCT TH 14	STREAM	1966	25.0	30.0	2	08-RUR/MINOR COLL	210	2001	2	32	30	8
LYON	CSAH 3	42511	005+00.990	0.9 MI N OF JCT CSAH 8	S BR YELLOW MEDICINE R	1966	26.0	31.0	2	07-RURAL COLL	670	2001	2	28	31	8
LYON	CSAH 7	42513	006+00.860	1.2 MI S OF JCT CSAH 2	BIG COTTONWOOD RIVER	1967	18.4	30.4	2	07-RURAL COLL	670	2001	2	28	30.4	9

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
LYON	CSAH 8	42516	004+00.140	0.1 MI E OF JCT CSAH 3	S BR YELLOW MEDICINE R	1970	26.0	30.2	2	07-RURAL COLL	220	2001	2	30	30.2	8
LYON	CSAH 11	42520	022+00.020	0.5 MI S OF JCT CSAH 8	REDWOOD RIVER	1971	26.0	32.0	2	08-RUR/MINOR COLL	170	2001	2	28	32	9
LYON	CSAH 10	42521	011+00.650	1.5 MI S OF CO LINE	YELLOW MEDICINE RIVER	1971	40.0	32.0	2	07-RURAL COLL	215	2001	2	32	32	9
LYON	CSAH 9	42522	018+00.850	1.2 MI S OF JCT CSAH 8	REDWOOD RIVER	1973	44.0	36.1	2	07-RURAL COLL	245	2001	2	30	36.1	9
LYON	CSAH 8	42523	012+00.000	0.2 MI W OF JCT CR 65	THREE MILE CREEK	1973	26.0	36.3	2	07-RURAL COLL	340	2001	2	26	36.3	9
LYON	CSAH 25	42526	001+00.290	1.7 MI SW OF JCT CSAH 5	REDWOOD RIVER	1975	32.0	32.0	2	09-RURAL LOCAL	255	2001	2	32	32	9
LYON	CSAH 13	42527	002+00.110	0.3 MI E OF JCT TH 23	REDWOOD RIVER	1978	32.0	32.0	2	09-RURAL LOCAL	70	2001	2	27	32	9
LYON	CSAH 5	42536	015+00.720	0.5 MI NW OF JCT CSAH 25	REDWOOD RIVER	1986	44.0	40.0	2	07-RURAL COLL	425	2001	2	40	40	9
LYON	CSAH 26	42538	000+00.280	0.1 MI E OF JCT CSAH 1	STREAM	1985	38.6	32.0	2	09-RURAL LOCAL	40	2001	2	32	32	9
LYON	CSAH 26	42540	005+00.040	0.1 MI W OF JCT CSAH 10	S BR YELLOW MEDICINE R	1989	44.5	32.0	2	09-RURAL LOCAL	40	2001	2	32	32	9

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LYON	CSAH 15	42542	000+00.790	0.3 MI N OF JCT TH 23	REDWOOD RIVER	1989	40.2	44.0	2	08-RUR/MINOR COLL	890	2001	2	44	44	9
LYON	CSAH 8	42546	010+00.710	1.2 MI E OF JCT TH 68	THREE MILE CREEK	1991	36.0	32.0	2	07-RURAL COLL	340	2001	2	34	32	9
LYON	CSAH 3	42547	004+00.890	0.1 MI S OF JCT CSAH 8	S BR YELLOW MEDICINE R	1991	63.6	32.0	2	07-RURAL COLL	420	2001	2	36	32	9
LYON	CSAH 11	42548	010+00.760	0.7 MI S OF JCT CSAH 20	COTTONWOOD RIVER	1992	41.0	40.0	2	07-RURAL COLL	275	2001	2	36	40	9
LYON	CSAH 1	42549	003+00.870	0.8 MI N OF JCT CSAH 26	N BR YELLOW MEDICINE R	1993	41.3	36.6	2	07-RURAL COLL	360	2001	2	32	36.6	8
LYON	CSAH 7	42555	016+00.550	0.3 MI S OF JCT TH 19	Three Mile Creek	2000	62.0	48.0	2	07-RURAL COLL	670	2001	2	48	48	9
LYON	CSAH 12	92692	004+00.080	1.5 MI W OF JCT TH 91	REDWOOD RIVER	1970	18.0	30.0	2	08-RUR/MINOR COLL	45	2001	2	36	30	8
LYON	CSAH 25	5101A	000+00.200	2.6 MI SW OF JCT CSAH 5	REDWOOD RIVER	1931	60.0	28.0	2	09-RURAL LOCAL	35	2001	2	24	28	8
LYON	CSAH 3	L1687	009+00.080	0.5 MI N OF JCT TH 68	S BR YELLOW MEDICINE R	1952	18.0	28.7	2	08-RUR/MINOR COLL	420	2001	2	28	28.7	8
LYON	CSAH 9	L1705	004+00.440	0.7 MI S OF JCT CSAH 2	COTTONWOOD RIVER	1956	18.0	24.4	2	08-RUR/MINOR COLL	330	2001	2	35	24.4	3

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LYON	CSAH 10	L1716	021+00.010	0.4 MI E OF JCT CSAH 23	DITCH	1940	21.3	27.8	2	07-RURAL COLL	295	2001	2	30	27.8	8
LYON	CSAH 25	R0122	000+00.910	0.8 MI SW OF LYND	REDWOOD RIVER	1925	47.5	15.8	1	09-RURAL LOCAL	35	2001	2	28	15.8	8
MOWER	CSAH 4	738	017+00.470	1.0 MI W OF JCT CSAH 7	STREAM	1917	25.4	28.0	2	08-RUR/MINOR COLL	370	1996	2	28	28	8
MOWER	CSAH 24	1750	001+00.060	1.1 MI N OF JCT CSAH 46	DOBBINS CREEK	1944	19.0	27.1	2	08-RUR/MINOR COLL	387	2000	2	28	27.1	8
MOWER	CSAH 4	3141	015+00.240	2.9 MI E OF JCT TH 56	LITTLE CEDAR RIVER	1963	23.0	30.1	2	08-RUR/MINOR COLL	370	1996	2	28	30.1	8
MOWER	CSAH 4	4570	016+00.720	1.2 MI W OF JCT CSAH 7	STREAM	1926	23.0	29.0	2	08-RUR/MINOR COLL	370	1996	2	28	29	8
MOWER	CSAH 11	4866	000+00.850	0.8 MI E OF JCT TH 56	UPPER IOWA RIVER	1929	35.0	30.0	2	07-RURAL COLL	130	1996	2	31	30	8
MOWER	CSAH 7	4872	027+00.560	1.7 MI N OF JCT CSAH 1	STREAM	1938	14.8	26.9	2	07-RURAL COLL	270	1996	2	30	26.9	8
MOWER	CSAH 46	5064	007+00.330	0.7 MI W OF JCT CSAH 24	STREAM	1931	31.0	27.0	2	07-RURAL COLL	1400	1996	2	32	27	8
MOWER	CSAH 46	5065	007+00.950	0.1 MI W OF JCT CSAH 24	STREAM	1931	39.8	27.0	2	07-RURAL COLL	1400	1996	2	32	27	8

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MOWER	CSAH 46	5066	009+00.250	0.8 MI W OF JCT TH 56	STREAM	1931	40.2	27.0	2	07-RURAL COLL	330	1996	2	32	27	8
MOWER	CSAH 46	5067	009+00.690	0.4 MI W OF JCT TH 56	STREAM	1931	35.5	27.0	2	07-RURAL COLL	330	1996	2	32	27	8
MOWER	CSAH 8	6645	000+00.050	0.2 MI N OF JCT TH 56	UPPER IOWA RIVER	1948	36.0	24.0	2	07-RURAL COLL	450	1996	2	34	24	8
MOWER	CSAH 6	50505	012+00.630	1.4 MI W OF JCT CSAH 7	STREAM	1961	23.0	27.1	2	08-RUR/MINOR COLL	235	1996	2	28	27.1	8
MOWER	CSAH 4	50508	003+00.440	0.6 MI E OF JCT TH 105	CEDAR RIVER	1965	75.0	27.9	2	08-RUR/MINOR COLL	300	1996	2	31	27.9	8
MOWER	CSAH 19	50509	007+00.970	1.6 MI S OF JCT CSAH 3	ROSE CREEK	1965	31.1	29.7	2	08-RUR/MINOR COLL	400	1996	2	30	29.7	8
MOWER	CSAH 1	50510	018+00.240	1.3 MI E OF JCT CSAH 7	N BR ROOT RIVER	1965	31.5	29.6	2	07-RURAL COLL	340	1996	2	30	29.6	8
MOWER	CSAH 29	50511	000+00.350	0.3 MI N OF JCT CSAH 4	ROSE CREEK	1966	56.0	29.2	2	07-RURAL COLL	550	1996	2	32	29.2	8
MOWER	CSAH 2	50525	027+00.150	0.9 MI E OF JCT CSAH 8	BEAR CREEK	1972	31.0	33.8	2	07-RURAL COLL	250	1996	2	34	33.8	8
MOWER	CSAH 6	50530	006+00.380	1.0 MI E OF JCT CSAH 105	OTTER CREEK	1974	31.1	37.0	2	08-RUR/MINOR COLL	560	1996	2	30	37	8

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MOWER	CSAH 7	50536	006+00.550	0.1 MI S OF JCT TH 56	LITTLE CEDAR RIVER	1975	31.0	39.5	2	07-RURAL COLL	1150	1996	2	31	39.5	8
MOWER	CSAH 12	50540	001+00.680	0.7 MI N OF JCT TH 56	UPPER IOWA RIVER	1977	60.0	36.0	2	09-RURAL LOCAL	1200	1996	2	42	36	8
MOWER	CSAH 13	50541	008+00.154	1.4 MI W OF JCT CSAH 8	DEER CREEK	1977	31.1	34.2	2	08-RUR/MINOR COLL	55	1996	2	35	34.2	8
MOWER	CSAH 7	50542	028+00.540	2.7 MI N OF JCT CSAH 1	N BR ROOT RIVER	1977	31.1	37.3	2	07-RURAL COLL	270	1996	2	30	37.3	8
MOWER	CSAH 29	50547	001+00.920	0.1 MI S OF JCT CSAH 28	STREAM	1979	82.0	44.6	2	07-RURAL COLL	600	1996	2	36	44.6	9
MOWER	CSAH 6	50551	014+00.640	0.6 MI E OF JCT CSAH 7	LITTLE CEDAR RIVER	1982	44.3	32.6	2	08-RUR/MINOR COLL	260	1996	2	29	32.6	9
MOWER	CSAH 19	50556	013+00.380	2.3 MI N OF JCT CSAH 46	DOBBINS CREEK	1979	36.3	32.0	2	09-RURAL LOCAL	130	1996	2	32	32	9
MOWER	CSAH 4	50582	001+00.660	1.1 mi W of jct TH 105	Orchard Creek	2001	31.0	36.0	2	08-RUR/MINOR COLL	256	2001	2	36	36	8
MOWER	CSAH 5	89212	000+00.010	2.0 MI W OF JCT TH 105	WOODBURY CREEK	1939	27.5	23.0	2	07-RURAL COLL	220	1996	2	26	23	8
MOWER	CSAH 16	89225	005+00.550	1.5 MI S OF JCT CSAH 2	WOLF CREEK	1954	28.9	24.1	2	07-RURAL COLL	380	1996	2	24	24.1	8

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MOWER	CSAH 4	92137	017+00.970	0.5 MI W OF JCT CSAH 7	STREAM	1963	29.2	30.4	2	08-RUR/MINOR COLL	370	1996	2	28	30.4	8
OLMSTED	CSAH 18	448	000+00.630	0.6 MI N OF JCT TH 52	MID FK ZUMBRO RIVER	1918	208.2	40.0	2	07-RURAL COLL	1950	2002	2	40	40	8
OLMSTED	CSAH 6	6643	007+00.200	0.5 MI W OF JCT TH 63	CARYS CREEK	1948	50.3	24.0	2	07-RURAL COLL	1400	2002	2	25	24	5
OLMSTED	CSAH 36	55023	000+00.167	0.3 MI N OF JCT TH 52	MARION CREEK	1970	45.9	36.2	2	07-RURAL COLL	4550	2002	2	36	36.2	8
OLMSTED	CSAH 15	55507	002+00.800	0.2 MI S OF JCT CR 126	S FK ZUMBRO RIVER	1962	61.5	30.0	2	08-RUR/MINOR COLL	560	2002	2	32	30	8
OLMSTED	CSAH 15	55508	005+00.800	0.8 MI S OF JCT CSAH 25	SALEM CREEK	1962	60.3	30.0	2	08-RUR/MINOR COLL	800	2002	2	34	30	8
OLMSTED	CSAH 26	55511	000+00.350	1.6 MI W OF JCT CSAH 3	S FK ZUMBRO RIVER	1964	60.0	30.0	2	07-RURAL COLL	240	2002	2	32	30	8
OLMSTED	CSAH 10	55513	014+00.290	0.4 MI N OF JCT CSAH 9	MID FK WHITEWATER RIVER	1965	31.2	29.8	2	07-RURAL COLL	1200	2002	2	32	29.8	8
OLMSTED	CSAH 7	55516	005+00.500	2.1 MI N OF JCT TH 52	STREAM	1968	84.0	32.0	2	06-RUR/MINOR ART	940	2002	2	42	32	8
OLMSTED	CSAH 20	55518	002+00.280	0.3 MI N OF JCT CR 120	N BR ROOT RIVER	1971	74.4	32.0	2	09-RURAL LOCAL	600	2002	2	36	32	8

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OLMSTED	CSAH 25	55522	011+00.226	0.3 MI E OF JCT US 52	S FK ZUMBRO RIVER	1975	124.0	52.0	4	16-URB/MINOR ART	18900	2002	2	48	52	9
OLMSTED	CSAH 3	55528	028+00.350	0.1 MI W OF JCT CSAH 12	S BR MID FK ZUMBRO RIVER	1979	85.5	44.0	2	07-RURAL COLL	910	2002	2	40	44	8
OLMSTED	CSAH 31	55533	002+00.060	1.3 MI S OF JCT TH 52	MID FK ZUMBRO RIVER	1981	88.2	32.0	2	09-RURAL LOCAL	140	2002	2	32	32	8
OLMSTED	CSAH 32	55535	003+00.510	0.1 MI S OF JCT TH 14	S FK WHITEWATER RIVER	1978	31.7	32.0	2	09-RURAL LOCAL	220	2002	2	24	32	5
OLMSTED	CSAH 1	55536	003+00.520	2.3 MI S OF JCT CSAH 16	N BR ROOT RIVER	1981	70.6	44.0	2	07-RURAL COLL	1700	2002	2	40	44	7
OLMSTED	CSAH 3	55543	008+00.500	0.1 MI N OF JCT CR 126	S BR ZUMBRO RIVER	1985	55.0	40.0	2	07-RURAL COLL	500	2002	2	40	40	8
OLMSTED	CSAH 36	55551	003+00.112	1.8 MI SW OF JCT TH 14	BEAR CREEK	1994	32.2	68.0	4	16-URB/MINOR ART	5200	2002	2	64	68	9
OLMSTED	CSAH 22	55561	004+00.761	0.1 MI N OF JCT TH 14	DM&E RR	1996	66.2	36.0	6	14-URB/OTH PR ART	14900	2002	2	98	90	8
OLMSTED	CSAH 8	55567	013+00.440	0.1 mi S of jct CSAH 22	S FK Zumbro River	2002	115.7	28.0	4	16-URB/MINOR ART	6500	2002	2	56	56	8
OLMSTED	CSAH 24	89179	003+00.980	0.4 MI E OF JCT CR 102	N FK WHITEWATER RIVER	1953	30.0	29.0	2	08-RUR/MINOR COLL	760	2002	2	32	29	8

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OLMSTED	CSAH 30	89181	004+00.170	1.0 MI E OF JCT CR 130	TROUT CREEK	1956	15.2	24.0	2	08-RUR/MINOR COLL	140	2002	2	30	24	8
ROCK	CSAH 3	3295	012+00.990	1.9 MI N OF JCT CSAH 4	ELK CREEK	1920	30.0	27.0	2	07-RURAL COLL	245	2002	2	27	27	8
ROCK	CSAH 3	3298	008+00.860	0.7 MI N OF JCT CSAH 16	STREAM	1920	20.1	28.4	2	07-RURAL COLL	630	2002	2	28	28.4	8
ROCK	CSAH 3	3299	012+00.820	1.7 MI N OF JCT CSAH 4	ELK CREEK	1920	22.9	27.0	2	07-RURAL COLL	245	2002	2	27	27	8
ROCK	CSAH 4	5050	014+00.015	0.1 MI E OF JCT CSAH 18	ROCK RIVER	1931	43.0	30.0	2	07-RURAL COLL	3050	2002	2	48	30	8
ROCK	CSAH 9	5348	008+00.140	0.9 MI S OF JCT CSAH 16	ELK CREEK	1933	49.7	30.3	2	08-RUR/MINOR COLL	440	2002	2	33	30.3	8
ROCK	CSAH 15	5497	015+00.560	1.5 MI E OF JCT CSAH 3	KANARANZI CREEK	1935	49.9	30.3	2	08-RUR/MINOR COLL	125	2002	2	32	30.3	8
ROCK	CSAH 8	7122	016+00.240	0.4 MI E OF JCT CSAH 19	ROCK RIVER	1954	59.5	24.0	2	08-RUR/MINOR COLL	385	2002	2	30	24	8
ROCK	CSAH 1	67501	007+00.630	1.6 MI E OF JCT CSAH 3	KANARANZI CREEK	1961	39.8	28.1	2	07-RURAL COLL	510	2002	2	26	28.1	8
ROCK	CSAH 1	67502	001+00.740	0.3 MI W OF JCT CSAH 9	ROCK RIVER	1968	42.0	30.3	2	07-RURAL COLL	420	2002	2	30	30.3	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ROCK	CSAH 7	67503	017+00.040	0.9 MI W OF JCT CSAH 2	ROCK RIVER	1969	36.0	36.1	2	07-RURAL COLL	680	2002	2	40	36.1	8
ROCK	CSAH 6	67504	008+00.680	0.6 MI N OF JCT CSAH 4	BEAVER CREEK	1972	36.0	36.0	2	07-RURAL COLL	415	2002	2	34	36	8
ROCK	CSAH 5	67505	009+00.670	0.4 MI W OF JCT CSAH 11	LITTLE BEAVER CREEK	1971	26.0	36.3	2	07-RURAL COLL	750	2002	2	28	36.3	8
ROCK	CSAH 7	67506	000+00.380	2.1 MI W OF JCT TH 23	SPLIT ROCK CREEK	1973	26.0	32.1	2	07-RURAL COLL	170	2002	2	32	32.1	8
ROCK	CSAH 9	67507	017+00.430	0.6 MI S OF JCT CSAH 8	CHAMPEPADAN CREEK	1971	26.0	32.0	2	08-RUR/MINOR COLL	125	2002	2	30	32	8
ROCK	CSAH 21	67510	004+00.620	0.3 MI W OF JCT CSAH 2	ROCK RIVER	1979	31.7	32.0	2	09-RURAL LOCAL	40	2002	2	34	32	8
ROCK	CSAH 15	67512	007+00.750	0.7 MI E OF JCT TH 75	ROCK RIVER	1991	66.0	28.0	2	09-RURAL LOCAL	145	2002	2	28	28	8
ROCK	CSAH 1	67529	001+00.250	1.3 MI E OF JCT TH 75	ASH CREEK	1991	32.0	32.2	2	07-RURAL COLL	420	2002	2	34	32.2	8
ROCK	CSAH 1	67530	001+00.420	1.5 MI E OF JCT TH 75	ASH CREEK OVERFLOW	1991	24.0	32.1	2	07-RURAL COLL	420	2002	2	34	32.1	8
ROCK	CSAH 1	67531	001+00.560	1.6 MI E OF JCT TH 75	ROCK RIVER OVERFLOW	1991	31.6	32.3	2	07-RURAL COLL	420	2002	2	34	32.3	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ROCK	CSAH 3	67538	016+00.360	0.3 MI N OF JCT CSAH 8	CHAMPEPADAN CREEK	1999	29.2	39.4	2	07-RURAL COLL	470	2002	2		39.4	9
ROCK	CSAH 3	67540	001+00.090	2.0 MI S OF JCT CSAH 1	KANARANZI CREEK	2000	56.0	36.0	2	07-RURAL COLL	190	2002	2		36	8
ROCK	CSAH 4	67544	014+00.525	0.6 mi E of jct CSAH 18	ROCK RIVER OVERFLOW	2002	42.0	44.0	2	07-RURAL COLL	2600	2002	2	36	44	8
ROCK	CSAH 9	92429	001+00.290	1.7 MI S OF JCT CSAH 1	STREAM	1965	22.2	30.6	2	08-RUR/MINOR COLL	215	2002	2	30	30.6	8
ROCK	CSAH 11	92583	016+00.470	0.7 MI N OF JCT CSAH 20	LITTLE BEAVER CREEK	1969	24.0	30.0	2	08-RUR/MINOR COLL	70	2002	2	38	30	8
ROCK	CSAH 8	92759	015+00.620	0.2 MI S OF JCT CSAH 19	MOUND CREEK	1960	17.2	28.1	2	08-RUR/MINOR COLL	385	2002	2	30	28.1	8
ROCK	CSAH 8	92760	020+00.630	0.2 MI W OF JCT CSAH 3	CHAMPEPADAN CREEK	1960	17.0	28.2	2	08-RUR/MINOR COLL	200	2002	2	30	28.2	8
ROCK	CSAH 7	92762	008+00.440	0.4 MI E OF JCT CR 66	STREAM	1959	22.0	28.7	2	07-RURAL COLL	175	2002	2	30	28.7	8
ROCK	CSAH 6	92763	007+00.940	0.2 MI S OF JCT CSAH 4	SPRING BROOK	1957	18.6	40.4	2	07-RURAL COLL	670	2002	2	40	40.4	8
ROCK	CSAH 1	L1942	007+00.690	1.8 MI E OF JCT CSAH 3	STREAM	1949	22.0	26.8	2	07-RURAL COLL	510	2002	2	26	26.8	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ROCK	CSAH 3	L1945	000+00.850	2.3 MI S OF JCT CSAH 1	STREAM	1959	23.4	28.2	2	07-RURAL COLL	190	2002	2	30	28.2	4
ROCK	CSAH 3	L1991	015+00.790	0.3 MI S OF JCT CSAH 8	STREAM	1949	24.0	28.5	2	07-RURAL COLL	245	2002	2	30	28.5	8
ROCK	CSAH 17	L2017	001+00.150	0.9 MI S OF JCT CSAH 13	BLOOD RUN	1960	22.0	28.3	2	07-RURAL COLL	560	2002	2	26	28.3	8
ROCK	CSAH 8	L2069	008+00.210	0.9 MI W OF JCT CSAH 11	BEAVER CREEK	1940	38.0	26.9	2	09-RURAL LOCAL	250	2002	2	32	26.9	8
ROCK	CSAH 7	L2106	013+00.330	0.3 MI E OF JCT TH 75	MOUND CREEK	1959	23.9	44.6	2	07-RURAL COLL	1100	2002	2	44	44.6	8
ROCK	CSAH 9	L2120	006+00.870	0.8 MI N OF JCT CSAH 15	STREAM	1920	31.9	30.6	2	08-RUR/MINOR COLL	440	2002	2	30	30.6	8
ROCK	CSAH 11	L2129	012+00.020	0.4 MI S OF JCT CSAH 8	LITTLE BEAVER CREEK	1954	17.0	24.5	2	08-RUR/MINOR COLL	70	2002	2	28	24.5	8
ROCK	CSAH 11	L2130	011+00.040	0.6 MI N OF JCT CSAH 5	LITTLE BEAVER CREEK	1954	23.0	24.4	2	08-RUR/MINOR COLL	70	2002	2	28	24.4	8
ROCK	CSAH 13	L2135	003+00.480	1.6 MI W OF JCT CSAH 6	STREAM	1952	23.8	28.3	2	07-RURAL COLL	1200	2002	2	36	28.3	7
ROCK	CSAH 13	L2136	000+00.560	0.5 MI W OF JCT CSAH 17	BLOOD RUN	1952	23.9	28.4	2	07-RURAL COLL	990	2002	2	36	28.4	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
ROCK	CSAH 16	L2146	000+00.740	0.7 MI E OF JCT TH 75	ROCK RIVER	1951	64.3	22.0	2	08-RUR/MINOR COLL	310	2002	2	28	22	8
ROCK	CSAH 16	L2147	004+00.320	0.3 MI E OF JCT CR 55	ELK CREEK	1949	25.0	24.2	2	08-RUR/MINOR COLL	80	2002	2	32	24.2	8
ROCK	CSAH 17	L2148	011+00.078	0.3 MI W OF JCT CSAH 4	BEAVER CREEK	1942	20.0	24.0	2	08-RUR/MINOR COLL	115	2002	2	26	24	8
ROCK	CSAH 19	L2150	004+00.040	0.1 MI S OF JCT CSAH 7	STREAM	1960	21.9	28.0	2	08-RUR/MINOR COLL	70	2002	2	32	28	8
ROCK	CSAH 20	L2153	008+00.450	1.5 MI W OF JCT CSAH 11	BEAVER CREEK	1952	19.0	24.3	2	08-RUR/MINOR COLL	195	2002	2	26	24.3	8
WATON-WAN	CSAH 3	4422	005+00.610	0.4 MI W OF JCT CSAH18	BUTTERFIELD CREEK	1925	29.9	36.4	2	07-RURAL COLL	600	2001	2	32	36.4	8
WATON-WAN	CSAH 32	4795	003+00.140	0.8 MI S OF JCT TH30	WATONWAN RIVER	1928	30.0	26.8	2	09-RURAL LOCAL	105	2001	2	32	26.8	8
WATON-WAN	CSAH 32	4819	004+00.840	0.9 MI N OF JCT TH 30	STREAM	1928	20.5	23.9	2	09-RURAL LOCAL	50	2001	2	35	23.9	8
WATON-WAN	CSAH 1	5354	002+00.710	0.3 MI W OF JCT CSAH18	N FK WATONWAN RIVER	1934	50.0	24.2	2	09-RURAL LOCAL	35	2001	2	30	24.2	8
WATON-WAN	CSAH 1	5861	008+00.690	0.2 MI E OF JCT TH4	N FK WATONWAN RIVER	1939	51.5	24.2	2	09-RURAL LOCAL	115	2001	2	32	24.2	8

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
WATON-WAN	CSAH 18	5935	006+00.720	0.6 MI N OF JCT CSAH1	N FK WATONWAN RIVER	1941	52.0	24.8	2	07-RURAL COLL	150	2001	2	32	24.8	8
WATON-WAN	CSAH 4	6111	002+00.000	2.0 MI N OF JCT TH30	N FK WATONWAN RIVER	1900	45.0	25.5	2	07-RURAL COLL	250	2001	2	36	25.5	8
WATON-WAN	CSAH 9	83001	009+00.232	0.3 MI NW OF JCT TH 15	WATONWAN RIVER	1974	73.8	44.0	2	07-RURAL COLL	1150	2001	2	44	44	9
WATON-WAN	CSAH 26	83505	001+00.790	1.2 MI W OF JCT CSAH9	DITCH	1964	23.1	32.5	2	07-RURAL COLL	100	2001	2	32	32.5	8
WATON-WAN	CSAH 10	83511	015+00.790	1.9 MI W OF JCT CSAH 12	S FK WATONWAN RIVER	1977	50.0	36.0	2	07-RURAL COLL	210	2001	2	36	36	8
WATON-WAN	CSAH 16	83516	012+00.470	0.2 MI S OF JCT CSAH 3	WATONWAN RIVER	1979	36.3	32.0	2	08-RUR/MINOR COLL	95	2001	2	32	32	8
WATON-WAN	CSAH 16	83521	006+00.330	2.0 MI E OF JCT CSAH 13	S FK WATONWAN RIVER	1987	46.3	32.0	2	08-RUR/MINOR COLL	55	2001	2	32	32	8
WATON-WAN	CSAH 13	83524	007+00.990	0.1 MI W OF JCT CR 109	S FK WATONWAN RIVER	1984	44.3	41.6	2	07-RURAL COLL	820	2001	2	40	41.6	8
WATON-WAN	CSAH 1	83525	006+00.340	0.2 MI N OF JCT CSAH 32	N FK WATONWAN RIVER	1992	28.3	32.0	2	09-RURAL LOCAL	65	2001	2	32	32	9
WATON-WAN	CSAH 27	83536	009+00.870	0.4 MI E OF JCT CSAH 56	ST JAMES CREEK	1996	22.0	44.1	2	07-RURAL COLL	1450	2001	2	40	44.1	9

County Name	Facility	Bridge No.	Ref. Point	Location	Feature Intersected	Year Built	Max Span	Deck Width	Lane No.	Functional Class	ADT Total	ADT Yr	Traf. Dir.	Appr. Width	Road Width	Appr. Algnmt. Rating
WATON-WAN	CSAH 1	83541	007+00.990	0.5 MI W OF JCT TH 4	N FK WATONWAN RIVER	1998	40.6	31.4	2	09-RURAL LOCAL	65	2001	2	28	31.4	8
WATON-WAN	CSAH 18	90339	000+00.840	0.8 MI N OF JCT CSAH 3	BUTTERFIELD CREEK	1962	32.5	24.0	2	08-RUR/MINOR COLL	40	2001	2	30	24	8
WATON-WAN	CSAH 5	92417	016+00.426	1.9 MI N OF JCT TH30	N FK WATONWAN RIVER	1923	44.0	32.4	2	08-RUR/MINOR COLL	560	2001	2	32	32.4	8

APPENDIX E

Database Query: Fixed-Object and Run-Off-Road Crashes Occurring at Sample CSAH Bridges, 1988 - 2002

Table E-1. Fixed-Object and Run-Off-Road Crashes Occurring at Bridges WITH Approach Guardrail, 1988-2002

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
02000001	003+00.989	2541	26,758	B	24	7-Sat	4	2003	603	40	4	1	1	1	1	031550079
02000001	003+00.960	2541	26,758	N	26	7-Sat	1	1997	0	40	3	4	1	3	1	970110180
02000001	008+00.904	92164	40,306	B	26	2-Mon	7	2000	700	45	3	1	2	1	2	001850144
02000001	008+00.926	92164	40,306	B	31	7-Sat	11	1988	1000	50	2	1	4	5	1	883100262
02000001	008+00.884	92164	40,306	B	32	7-Sat	11	1988	1800	50	3	4	4	5	1	883100422
02000001	008+00.884	92164	40,306	N	32	7-Sat	11	1988	1900	50	3	4	4	5	1	883100601
02000001	008+00.882	92164	40,306	N	51	1-Sun	4	1990	2300	45	1	6	3	2	2	900980004
02000001	008+00.884	92164	40,306	N	31	5-Thur	10	1991	1200	50	1	1	4	3	2	913040207
02000001	008+00.891	92164	40,306	N	31	6-Fri	3	1992	1500	50	90	1	4	5	2	920730312
02000001	008+00.903	92164	40,306	C	31	6-Fri	5	1992	100	45	1	4	2	1	1	921220265
02000001	009+00.016	92164	40,306	N	31	1-Sun	11	1992	1200	40	1	1	1	1	1	923200172
02000001	009+00.016	92164	40,306	B	34	3-Tue	2	1993	600	45	1	4	5	5	1	930400198
02000002	000+00.200	2523	9,103	A	51	3-Tue	6	1989	100	30	1	4	1	1	11	891780090
02000002	000+00.189	2523	9,103	C	31	2-Mon	1	1999	900	30	2	1	1	5	1	990040503
02000007	007+00.722	2526	8,708	N	51	5-Thur	12	1991	500	55	1	6	5	5	4	913460323
02000007	007+00.644	2526	8,708	B	51	6-Fri	9	1995	500	99	1	99	99	5	2	952650131
02000007	013+00.211	2535	6,241	N	51	6-Fri	3	1993	1500	55	90	1	2	1	4	930780264
02000007	013+00.211	2535	6,241	B	51	1-Sun	4	1994	2500	55	1	4	1	1	1	941070192
02000007	013+00.211	2535	6,241	N	37	3-Tue	7	1995	2000	55	1	3	2	2	1	952060304
02000009	007+00.336	2536	10,380	B	31	5-Thur	2	2002	600	55	1	1	3	2	2	020450216
02000009	007+00.395	2536	10,380	B	51	1-Sun	12	1989	1900	55	1	6	2	2	2	893650221
02000009	007+00.395	2536	10,380	A	30	5-Thur	3	1990	1100	55	1	1	4	3	1	900670367
02000009	007+00.395	2536	10,380	N	31	3-Tue	7	1991	2100	55	1	5	1	1	1	912040171
02000009	007+00.386	2536	10,380	A	51	6-Fri	8	1992	100	55	2	6	1	1	1	922410008
02000009	007+00.395	2536	10,380	N	26	7-Sat	2	1994	300	55	90	6	1	1	1	940360172
02000009	007+00.416	2536	10,380	N	51	3-Tue	1	1996	1900	55	1	6	1	5	2	960300348
02000011	004+00.428	2553	13,770	C	25	2-Mon	11	1996	1600	45	1	1	2	1	1	963230168
02000013	000+00.764	2518	1,976	N	25	1-Sun	12	1992	2100	55	99	6	5	5	1	923480079
02000014	016+00.405	2527	7,201	N	51	4-Wed	12	2000	2300	50	99	6	4	5	1	003480447
02000014	001+00.111	2560	20,076	N	26	1-Sun	11	2000	0	55	2	6	4	3	1	003240528
02000014	000+00.998	2560	20,076	N	35	4-Wed	10	1988	2300	50	3	4	1	1	1	882930297
02000014	000+00.998	2560	20,076	N	28	3-Tue	12	1988	800	55	2	1	2	5	2	883480150
02000014	001+00.149	2560	20,076	N	31	4-Wed	3	1994	1700	45	90	1	5	5	2	940820275
02000014	000+00.993	2560	20,076	B	31	4-Wed	3	1994	1800	40	1	4	5	5	1	940820565
02000014	001+00.111	2560	20,076	B	37	6-Fri	10	1996	1900	55	3	4	1	1	99	962850051

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
02000014	001+00.000	2560	20,076	B	30	7-Sat	11	1998	800	55	99	1	1	1	2	983110208
02000018	002+00.596	2549	14,479	N	35	6-Fri	1	2000	800	45	99	1	1	5	1	000210535
02000018	002+00.621	2549	14,479	N	31	5-Thur	12	2000	900	45	1	1	4	5	2	003630748
02000018	002+00.559	2549	14,479	N	32	6-Fri	1	2001	800	45	1	1	4	3	1	010260770
02000018	002+00.554	2549	14,479	C	31	3-Tue	3	2002	2000	45	2	4	4	3	1	020640038
02000018	002+00.564	2549	14,479	N	37	3-Tue	1	2003	1107	45	4	1	2	5	1	031010108
02000018	002+00.621	2549	14,479	N	35	1-Sun	12	1998	1000	45	90	1	4	3	1	983540105
02000021	006+00.111	90734	800	N	28	7-Sat	3	1989	2100	50	90	6	1	5	2	890630425
02000021	006+00.111	90734	800	B	51	1-Sun	10	1989	100	50	1	6	1	1	1	892740237
02000021	006+00.070	90734	800	C	90	1-Sun	5	1998	1900	55	99	3	1	1	1	981370045
02000022	008+00.787	2519	8,586	A	31	3-Tue	1	1990	1400	55	1	1	3	5	1	900160157
02000022	012+00.166	2519	8,586	C	31	3-Tue	9	1992	100	55	1	6	1	1	4	922590283
02000022	008+00.780	2519	8,586	N	31	1-Sun	2	1996	100	55	1	6	2	3	2	960560053
02000022	005+00.020	2548	5,464	K	37	6-Fri	11	1993	100	55	2	6	2	1	2	933230002
02000024	009+00.107	2501	9,400	B	25	5-Thur	3	2000	700	55	90	1	2	3	1	000690103
02000024	009+00.030	2501	9,400	B	27	7-Sat	8	1988	500	55	90	2	1	1	1	882190048
02000024	017+00.590	92730	1,000	N	51	4-Wed	3	2001	1900	55	2	6	1	1	1	010660132
02000024	017+00.608	92730	1,000	N	51	5-Thur	11	1992	2300	99	90	99	99	5	4	923240343
02000116	001+00.952	2545	17,156	C	51	5-Thur	9	2003	1433	55	90	1	3	2	1	032940023
02000116	002+00.077	2545	17,156	N	41	2-Mon	2	1995	900	45	90	1	1	1	1	950580088
02000116	001+00.979	2545	17,156	N	31	6-Fri	2	1998	700	55	2	1	5	5	2	980440065
02000116	001+00.744	2546	17,156	N	31	2-Mon	1	1998	1400	55	1	1	4	3	1	980120602
02000116	005+00.041	2564	20,558	N	51	6-Fri	10	1991	900	99	1	99	99	1	1	912770356
02000116	005+00.111	2564	20,558	B	51	4-Wed	11	1994	1400	55	1	1	1	1	35	943130191
02000116	001+00.869	96834	17,156	N	31	3-Tue	12	2000	900	45	1	1	2	5	2	003470382
02000116	001+00.919	96834	17,156	B	41	5-Thur	4	2003	2106	55	2	6	5	5	3	030950044
18000003	001+00.541	6518	8,600	N	30	3-Tue	12	1993	2300	50	90	6	2	5	1	933620236
18000003	001+00.504	6518	8,600	N	37	3-Tue	12	1993	2300	55	99	6	7	5	1	933620272
18000003	001+00.434	6518	8,600	N	51	3-Tue	2	1997	1700	50	1	3	2	2	35	970490305
18000011	018+00.450	18524	1,050	N	31	7-Sat	4	2001	1800	55	1	6	2	1	1	011180221
18000011	018+00.441	18524	1,050	N	51	3-Tue	1	1992	1500	55	99	1	2	5	2	920140296
18000011	018+00.450	18524	1,050	A	51	3-Tue	8	1993	100	55	1	6	1	1	1	932430171
18000011	018+00.460	18524	1,050	B	51	7-Sat	5	1995	2000	55	2	3	2	1	2	951470372
18000016	012+00.111	18501	2,550	C	25	7-Sat	6	1994	100	30	99	6	99	2	1	941760258
18000016	012+00.160	18501	2,550	A	30	4-Wed	8	1995	1100	50	2	1	1	1	1	952420123
18000021	001+00.111	18523	530	C	30	6-Fri	6	2002	2000	55	1	1	1	1	1	021790249
18000021	001+00.155	18523	530	C	31	1-Sun	1	1994	1700	55	90	6	7	3	1	940090192

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
18000031	003+00.495	18506	1,350	C	51	1-Sun	5	1998	2200	55	2	6	1	1	1	981370175
18000036	001+00.111	18518	1,100	N	41	7-Sat	12	2000	2100	55	3	6	99	5	2	003650213
18000036	001+00.100	18518	1,100	N	30	3-Tue	6	1988	100	55	90	6	1	1	2	881800153
18000036	001+00.090	18518	1,100	N	31	2-Mon	3	1999	1000	55	2	1	4	3	1	990670701
18000066	001+00.022	18510	5,100	N	51	4-Wed	4	1991	0	40	1	6	1	1	1	911000221
18000066	000+00.963	18510	5,100	N	90	1-Sun	8	1996	700	45	90	1	1	1	4	962310089
19000009	002+00.171	8433	3,300	N	51	5-Thur	6	2000	1700	55	2	1	1	1	1	001810300
19000009	002+00.170	8433	3,300	B	30	4-Wed	11	1988	1300	55	90	1	2	1	2	883350230
19000042	000+00.933	19511	39,500	N	51	3-Tue	11	2000	2000	50	1	4	4	5	1	003120577
19000046	022+00.246	19502	4,200	N	30	1-Sun	2	1996	0	30	1	4	1	90	1	960490153
19000047	014+00.823	L3170	2,250	N	31	3-Tue	4	2002	700	55	1	1	1	1	1	021060036
19000050	006+00.931	19J07	15,000	N	37	5-Thur	2	1991	2100	55	1	6	1	1	1	910520184
19000085	011+00.222	19504	890	N	31	1-Sun	12	1989	2300	55	2	6	99	99	1	893580035
19000085	011+00.140	19504	890	C	31	7-Sat	3	1996	0	99	1	99	99	1	2	960900036
19000086	009+00.840	L3182	2,200	N	25	5-Thur	10	1991	1500	55	1	1	7	5	2	913040125
23000001	020+00.820	5289	1,300	N	51	6-Fri	4	2003	345	0	0	6	5	5	1	040560320
23000001	020+00.800	5289	1,300	A	51	7-Sat	4	1989	400	55	1	6	2	1	1	891120024
23000001	020+00.770	5289	1,300	B	31	1-Sun	4	1999	2500	55	1	1	2	1	1	991080111
23000001	016+00.150	23507	1,300	B	31	7-Sat	8	1988	100	0	2	6	2	1	1	882400282
23000001	017+00.490	23508	1,300	C	31	1-Sun	12	1989	100	55	1	6	4	3	1	893580012
23000001	017+00.690	23508	1,300	C	31	2-Mon	2	1999	800	55	1	1	2	5	1	990320184
23000001	017+00.690	23508	1,300	C	31	2-Mon	2	1999	600	55	1	1	2	5	1	990460180
23000001	006+00.340	23514	900	N	31	1-Sun	1	2000	700	55	1	2	5	5	1	000090088
25000001	022+00.454	25559	1,100	N	30	4-Wed	12	1997	500	30	1	4	2	5	1	973440107
25000005	005+00.230	25566	650	C	90	6-Fri	12	1998	1700	55	1	6	1	1	2	983520151
25000014	004+00.200	25508	245	A	31	2-Mon	7	1991	600	55	1	2	1	1	31	911890032
25000017	003+00.000	25540	640	A	51	7-Sat	4	1991	1900	55	1	3	1	1	2	911170176
25000018	002+00.140	25505	7,400	B	33	2-Mon	11	1998	1700	55	1	6	3	2	1	983130218
25000018	002+00.690	25506	7,400	B	51	2-Mon	6	1988	9900	55	1	1	1	1	1	881580002
25000018	002+00.770	25506	7,400	B	51	2-Mon	3	1992	2000	55	1	6	2	1	1	920760181
25000030	008+00.887	25564	420	N	35	6-Fri	10	2000	1500	55	90	1	2	1	1	003010337
25000066	000+00.288	25517	6,700	B	26	5-Thur	6	2000	700	55	1	6	3	99	1	001530239
25000066	000+00.252	25517	6,700	N	31	6-Fri	4	1988	2100	30	2	5	3	2	1	881130125
25000066	000+00.300	25517	6,700	C	30	5-Thur	8	1988	200	55	90	4	2	1	2	882170114

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
25000066	000+00.360	25517	6,700	N	34	3-Tue	1	1991	1800	40	1	6	1	5	1	910220374
42000002	020+00.090	42557	244	A	51	1-Sun	8	1990	1700	55	1	1	1	1	12	902380189
42000013	019+00.470	42512	145	C	51	4-Wed	9	1998	800	55	2	1	2	1	2	982450176
42000013	017+00.430	42514	145	A	25	7-Sat	11	2001	100	55	1	6	1	1	1	013070259
42000033	003+00.457	42541	3,950	N	31	5-Thur	10	1991	1500	55	1	1	4	5	1	913040929
42000033	003+00.490	42541	3,950	N	26	3-Tue	11	1993	2000	55	1	99	1	5	2	933340371
42000033	003+00.509	42541	3,950	N	90	4-Wed	1	1997	1000	55	1	1	2	5	35	970080150
50000001	002+00.230	50504	410	N	31	2-Mon	8	1989	800	55	2	1	1	1	1	892260077
50000001	002+00.530	50504	410	B	31	2-Mon	3	1997	1700	55	2	1	1	1	2	970900207
50000002	004+00.500	50524	730	N	52	1-Sun	5	1991	1800	55	2	3	3	2	1	911250243
50000005	002+00.232	7016	210	N	35	7-Sat	4	1988	500	55	1	1	3	2	1	881140257
50000005	002+00.185	7016	210	N	31	1-Sun	7	1993	1400	55	1	1	2	1	1	931850211
50000006	002+00.329	7091	640	B	25	2-Mon	10	2002	300	55	90	6	4	3	1	023010229
50000008	010+00.570	4569	315	C	51	3-Tue	9	1988	1100	55	1	1	1	1	11	882570167
50000008	013+00.220	50576	770	C	31	1-Sun	12	2000	300	55	99	6	7	3	1	003520262
50000014	000+00.180	7148	1,200	C	31	4-Wed	12	2001	500	30	2	6	4	3	1	013600097
50000014	000+00.211	7148	1,200	N	51	7-Sat	8	2003	1948	55	1	1	1	1	1	032750269
50000014	000+00.211	7148	1,200	B	26	7-Sat	11	2003	815	55	2	1	2	1	1	040050306
50000016	000+00.861	50503	2,100	C	51	5-Thur	5	1989	1900	30	1	1	1	1	1	891310138
50000023	000+00.930	7048	2,150	N	34	1-Sun	2	1989	1200	30	1	1	2	5	1	890360131
50000023	000+00.930	7048	2,150	B	31	6-Fri	11	1991	1100	30	99	1	5	5	1	913330331
50000023	000+00.945	7048	2,150	N	31	5-Thur	12	1998	2300	30	90	4	1	5	1	983650208
50000025	008+00.730	50507	230	B	31	5-Thur	12	2002	1900	55	1	6	4	5	1	023530505
50000025	008+00.750	50507	230	A	51	7-Sat	9	1988	0	55	1	6	1	1	1	882610038
50000025	000+00.111	50517	750	N	27	7-Sat	8	2001	1900	55	1	1	1	1	1	012370226
50000025	000+00.111	50517	750	B	31	1-Sun	3	1992	2000	30	2	5	6	1	1	920610125
50000029	003+00.748	5368	2,950	N	31	3-Tue	3	1989	1800	30	1	4	7	5	1	890730616
50000029	003+00.742	5368	2,950	N	31	5-Thur	2	1994	500	30	1	4	1	5	1	940340112
55000005	007+00.430	55527	2,300	N	51	5-Thur	3	1988	1900	55	1	4	1	1	1	880910034
55000012	009+00.701	55520	1,950	B	37	6-Fri	7	1991	1700	55	2	1	1	1	4	912000283
55000022	011+00.265	55519	25,500	B	31	5-Thur	10	2000	500	40	1	6	1	1	1	002860335
55000022	011+00.326	55519	25,500	N	31	5-Thur	4	1991	100	40	1	6	2	1	2	911080167
55000022	011+00.315	55519	25,500	N	31	7-Sat	3	1994	0	40	1	6	2	1	1	940850227
55000022	011+00.326	55519	25,500	N	31	7-Sat	6	1994	2200	40	1	6	1	1	1	941620139

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
55000022	011+00.265	55519	25,500	B	31	3-Tue	10	1995	2300	99	1	4	3	2	2	953040220
55000022	011+00.282	55519	25,500	C	31	7-Sat	4	1997	2300	40	2	6	1	1	1	971020095
55000022	011+00.288	55519	25,500	N	31	7-Sat	11	1997	300	40	1	6	6	90	1	973330238
55000022	011+00.176	55519	25,500	C	31	2-Mon	1	1998	2200	40	1	6	5	3	1	980260299
55000022	011+00.315	55519	25,500	N	51	6-Fri	4	1998	2500	55	99	6	1	1	1	981000250
55000022	011+00.232	55519	25,500	B	31	2-Mon	1	1999	1300	40	1	1	4	3	2	990110257
67000004	018+00.765	67524	1,450	N	31	4-Wed	2	1993	1900	55	1	6	7	5	1	930410103
67000017	006+00.310	6787	560	B	31	7-Sat	4	1998	1600	55	1	1	2	2	1	981150060
83000012	003+00.477	83513	255	C	51	4-Wed	3	1990	1700	55	90	1	5	5	1	900660447
83000012	003+00.480	83513	255	N	51	4-Wed	4	1998	2200	55	1	6	1	1	1	981190268
83000012	003+00.390	83513	255	N	31	2-Mon	9	1999	2100	55	90	6	2	90	2	992700240
83000019	006+00.920	90343	135	N	31	3-Tue	4	1989	1800	0	99	3	1	99	2	891010207
83000027	003+00.040	83539	1,200	N	31	5-Thur	6	1994	1900	45	2	1	1	1	35	941600143
83000027	003+00.000	83539	1,200	N	34	5-Thur	1	1995	1100	45	2	1	1	5	1	950050076
83000027	003+00.040	83539	1,200	B	31	1-Sun	5	1995	1300	45	2	1	3	2	1	951480159
83000057	000+00.457	8259	2,700	C	34	2-Mon	1	1992	1800	55	90	6	6	1	1	920060019

Table E-2. Fixed-Object and Run-Off-Road Crashes Occurring at Bridges WITHOUT Approach Guardrail, 1988-2002

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
02000051	003+00.666	2520	16,500	B	31	6-Fri	3	1995	0	50	2	6	1	1	2	950690128
18000001	015+00.099	6519	2,050	N	51	5-Thur	7	1993	2100	55	1	6	1	1	1	932100206
19000026	006+00.818	97556	10,400	C	90	3-Tue	8	2001	1100	45	1	1	99	1	1	012400274
19000031	002+00.111	19512	9,900	N	26	7-Sat	4	2000	2200	50	3	4	1	1	1	000920053
19000031	002+00.077	19512	9,900	N	38	3-Tue	4	1988	200	50	99	4	2	2	1	881170345
19000031	002+00.111	19512	9,900	N	90	4-Wed	8	1990	1500	50	1	1	1	1	1	902270266
19000054	002+00.640	2951	4,200	B	37	7-Sat	9	1988	300	55	90	6	1	1	1	882610119
19000068	001+00.987	19529	5,200	C	31	2-Mon	9	1988	1600	35	2	1	1	1	1	882700230
19000068	001+00.930	19529	5,200	N	31	1-Sun	4	1991	1600	55	1	1	2	2	1	911040152
19000068	002+00.160	19529	5,200	N	31	6-Fri	7	1994	1400	15	1	1	1	1	1	941820229
19000068	002+00.080	19529	5,200	B	31	6-Fri	8	1994	100	55	2	6	1	1	2	942310046
19000091	001+00.930	7271	120	N	51	1-Sun	10	1993	1700	55	1	1	1	1	2	932970181
19000091	001+00.930	7271	120	N	51	7-Sat	12	1993	0	55	1	6	1	5	2	933380104
23000002	016+00.796	23545	1,400	C	26	7-Sat	2	1989	1000	30	2	1	2	5	1	890490516
23000002	016+00.824	23545	1,400	N	31	7-Sat	3	1991	2200	30	2	4	2	2	2	910750085
23000002	016+00.805	23545	1,400	K	51	5-Thur	5	1991	2300	30	90	4	6	1	1	911290209
23000005	019+00.038	7959	680	N	51	6-Fri	10	2000	2300	99	1	6	3	2	1	002870122
23000005	018+00.968	7959	680	N	51	6-Fri	4	1991	2100	99	1	6	2	1	1	911160253
23000005	010+00.778	23522	430	C	51	6-Fri	1	1995	1400	55	1	1	4	5	1	950060466
23000008	033+00.500	23506	1,250	N	51	6-Fri	11	1997	600	55	99	2	1	5	1	973320317
23000011	012+00.190	23541	310	N	51	5-Thur	5	1989	2000	55	1	3	1	1	2	891310054
23000012	019+00.770	23512	760	A	31	6-Fri	11	1992	2200	55	1	6	1	5	1	923320204
23000012	019+00.770	23512	760	C	51	2-Mon	12	1993	900	55	2	1	4	5	1	933540349
23000012	016+00.481	23538	165	B	51	4-Wed	7	1990	2100	55	90	6	3	2	1	902060253
23000015	009+00.360	7979	245	N	51	5-Thur	11	1992	2300	99	1	99	99	1	1	923100033
23000015	000+00.780	7983	385	N	30	6-Fri	2	1996	1000	55	2	1	1	5	1	960330415
23000015	000+00.780	7983	385	N	37	7-Sat	9	1999	2500	55	99	6	1	99	1	992610193
23000021	023+00.420	23521	120	N	30	2-Mon	10	2001	2500	55	90	6	1	1	1	012950096
23000025	013+00.690	9923	255	N	90	6-Fri	11	1997	1900	55	99	6	4	3	1	973180360
23000027	000+00.420	23559	290	N	51	1-Sun	10	2002	1200	55	90	1	1	1	4	022860099
23000029	002+00.960	9939	50	B	41	1-Sun	1	2000	300	55	1	6	99	5	1	000090158
23000038	003+00.000	23567	105	N	90	7-Sat	12	2001	900	99	99	1	5	5	4	013560635
23000038	002+00.966	23567	105	N	30	6-Fri	10	1994	2000	55	2	6	1	1	1	942870005
23000038	003+00.000	23567	105	N	31	3-Tue	8	1998	600	55	1	6	1	2	2	982160233
25000002	010+00.318	2103	820	N	31	2-Mon	12	2001	1300	55	1	1	1	3	1	013580148

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
25000002	010+00.435	2103	820	K	31	7-Sat	2	1993	1600	55	1	1	7	90	1	930440001
25000002	010+00.481	2103	820	N	90	7-Sat	6	1996	1700	55	2	1	1	1	2	961530102
25000006	006+00.018	25532	1,450	N	36	2-Mon	2	2003	1800	55	1	3	2	5	1	030970367
25000006	006+00.011	25532	1,450	N	51	7-Sat	1	1995	1600	55	1	1	7	1	1	950210284
25000007	020+00.407	25522	455	B	51	1-Sun	6	2002	800	55	1	1	1	1	1	021740176
25000007	020+00.417	25522	455	B	34	6-Fri	3	1988	300	55	90	6	99	1	1	880780255
25000007	020+00.429	25522	455	N	51	7-Sat	6	1990	200	55	1	6	1	1	1	901740199
25000007	020+00.407	25522	455	A	90	1-Sun	8	1990	1500	55	90	1	1	1	11	902380115
25000007	020+00.407	25522	455	N	51	7-Sat	11	1991	1600	55	2	3	4	5	1	913270387
25000007	020+00.507	25522	455	B	37	7-Sat	7	1995	1300	55	90	1	1	1	11	952100268
25000007	016+00.937	25530	320	A	51	5-Thur	3	2002	1800	55	2	6	5	5	1	020660229
25000007	017+00.091	25531	320	C	37	1-Sun	1	2002	2200	55	90	6	2	1	1	020270037
25000007	017+00.097	25531	320	B	51	7-Sat	7	2002	1700	55	1	1	1	8	2	022080261
25000007	017+00.097	25531	320	A	51	3-Tue	9	2003	201	55	4	6	1	1	3	032830020
25000007	017+00.197	25531	320	N	37	4-Wed	12	1999	2000	55	99	6	2	1	1	993490275
25000008	007+00.811	25516	395	C	37	7-Sat	8	1991	800	55	1	1	1	1	35	912360218
25000014	011+00.560	25534	1,000	B	51	2-Mon	11	1997	1700	55	1	6	2	1	1	973070180
42000003	012+00.860	7211	420	N	51	4-Wed	5	1994	800	55	2	1	1	1	32	941380225
42000005	015+00.691	42536	425	B	30	2-Mon	1	1990	9900	0	99	6	1	5	1	900010205
42000005	015+00.709	42536	425	A	51	6-Fri	6	1991	1900	30	1	1	1	1	11	911790214
42000008	010+00.630	42546	340	N	31	4-Wed	4	1990	2000	55	1	3	3	2	2	900940191
42000009	018+00.600	42522	245	C	31	6-Fri	5	1993	1900	55	1	3	8	2	2	931270218
42000009	004+00.402	L1705	330	K	30	6-Fri	5	1992	500	55	99	6	1	1	1	921500001
42000010	004+00.709	42505	380	N	31	7-Sat	11	1988	9900	0	99	2	5	3	1	883170689
42000010	011+00.665	42521	215	B	90	1-Sun	8	2000	200	55	90	6	1	1	1	002330051
50000004	017+00.970	92137	370	N	51	2-Mon	7	1988	900	55	2	1	1	1	38	881930193
50000005	000+00.014	89212	220	N	90	1-Sun	10	2001	1200	99	99	99	99	99	1	012870159
50000008	000+00.111	6645	450	C	36	3-Tue	7	2001	2000	99	90	1	1	99	10	012120256
50000012	001+00.670	50540	1,200	N	30	1-Sun	11	1992	1300	55	99	1	3	2	1	923060148
50000016	005+00.550	89225	380	A	51	7-Sat	7	2000	200	55	90	6	1	1	1	001970205
55000001	003+00.460	55536	1,700	N	31	2-Mon	9	2003	630	55	2	1	1	1	2	032930117
55000003	008+00.500	55543	500	B	51	3-Tue	3	2000	600	55	90	1	1	2	2	000740218
55000003	008+00.514	55543	500	N	37	4-Wed	9	2000	400	55	1	1	1	1	1	002710099
55000006	007+00.195	6643	1,400	N	30	7-Sat	1	2003	1248	55	1	1	5	4	2	030590002
55000006	007+00.260	6643	1,400	A	31	4-Wed	7	1997	1300	55	2	1	1	1	1	971970259
55000006	007+00.160	6643	1,400	N	31	1-Sun	8	1993	0	55	90	6	1	1	1	932340125
55000007	005+00.610	55516	940	N	31	1-Sun	11	1988	1000	55	1	1	4	5	1	883320225

Route	Ref Point	Bridge Num.	Pontis AADT	Sev	Acc. Type	Day of Week	Month	Year	Time	SL	Loca-tion	Light-ing	Weath-er	Road Surf.	Veh Type	Acc Num
55000015	005+00.800	55508	800	B	31	4-Wed	1	1992	900	55	99	1	2	8	1	920220081
55000015	005+00.813	55508	800	K	31	6-Fri	4	1993	0	55	1	6	1	1	1	931130001
55000020	002+00.250	55518	600	C	31	3-Tue	2	2002	800	55	1	1	7	5	1	020570174
55000022	004+00.766	55561	14,900	N	38	7-Sat	3	1988	1700	50	99	6	7	5	4	880720115
55000025	011+00.156	55522	18,900	N	31	7-Sat	3	1993	1500	35	1	1	1	1	4	930720120
55000025	011+00.196	55522	18,900	N	31	6-Fri	11	1993	700	35	1	1	4	5	2	933090667
55000030	004+00.170	89181	140	B	37	7-Sat	3	1990	1600	55	1	1	1	1	2	900620168
55000032	003+00.430	55535	220	N	31	3-Tue	2	1990	100	55	1	6	1	5	1	900510018
55000036	003+00.111	55551	5,200	B	51	6-Fri	3	1992	2100	55	1	6	6	2	2	920660076
55000036	003+00.111	55551	5,200	C	37	7-Sat	9	1995	1000	55	1	1	1	1	2	952520226
55000036	000+00.250	55023	4,550	C	31	3-Tue	6	2000	1600	55	1	1	3	2	1	001650148
67000001	007+00.618	67501	510	B	31	3-Tue	6	1999	1500	55	1	1	1	1	14	991590215
67000003	016+00.355	67538	470	K	31	4-Wed	7	1996	1800	55	1	1	1	1	1	962060002
67000003	008+00.890	3298	630	N	90	4-Wed	6	1993	1800	55	1	1	1	1	2	931740300
67000003	009+00.080	3298	630	N	31	6-Fri	11	1993	1100	55	1	1	3	5	1	933160297
67000003	012+00.740	3299	245	N	31	1-Sun	9	1991	100	55	2	6	1	1	1	912510175
67000003	001+00.111	67540	190	N	90	4-Wed	3	1989	900	55	2	1	1	5	38	890670284
67000004	013+00.993	5050	3,050	N	31	5-Thur	1	1996	1600	30	1	1	1	5	2	960040284
67000006	008+00.650	67504	415	A	31	3-Tue	3	2000	500	55	1	6	1	1	2	000670151
67000006	008+00.650	67504	415	B	51	2-Mon	12	1996	1800	55	1	3	7	5	2	963510387
67000007	013+00.210	L2106	1,100	C	31	7-Sat	3	1993	2000	55	1	6	6	1	2	930860150
67000008	016+00.210	7122	385	A	31	2-Mon	1	1993	700	55	1	6	1	99	1	930040239
67000008	016+00.210	7122	385	C	51	6-Fri	3	1995	700	55	1	2	2	1	1	950830213
67000008	020+00.590	92760	200	A	31	3-Tue	8	1991	100	55	1	6	2	1	1	912320191
67000009	006+00.870	L2120	440	N	31	1-Sun	9	1996	1500	55	1	1	2	1	1	962730012
67000013	003+00.480	L2135	1,200	C	31	3-Tue	5	1999	300	55	2	6	2	1	1	991240286
67000013	000+00.560	L2136	990	N	31	6-Fri	3	1989	1500	55	2	1	4	1	1	890760525
67000013	000+00.560	L2136	990	N	31	2-Mon	3	1992	1500	55	1	1	7	3	2	920690309
67000013	000+00.560	L2136	990	C	90	2-Mon	11	1997	1400	55	2	1	1	1	1	973210054
67000016	000+00.750	L2146	310	B	31	4-Wed	10	1992	2200	55	99	6	1	1	2	923020220
67000016	000+00.750	L2146	310	A	37	5-Thur	7	1996	200	55	1	6	2	2	1	961860211
67000016	000+00.750	L2146	310	N	31	7-Sat	7	1996	700	55	1	6	1	1	1	962020211
83000005	016+00.426	92417	560	B	30	2-Mon	3	1996	1000	55	90	1	2	1	35	960710083
83000027	009+00.870	83536	1,450	K	31	7-Sat	2	1994	1600	55	1	1	1	1	2	940570336
83000032	002+00.912	4795	105	N	31	7-Sat	6	1989	600	55	2	2	1	1	1	891610272

APPENDIX F

Summarized Police Report Information for Crashes at Sample CSAH Bridges

Table F-1. Summary of Crash Reports: Fixed-Object and ROR Crashes Occurring at Bridges WITHOUT Approach Guardrail, 1988 - 2002

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
2519	2000022	No	900160157	1990	A	31	Lost control on icy pavement, ROR and hit "bridge guard fence" on the NE corner. (diag shows direct strike on end of BR on right approach but NO GR shown)	BR	Yes (Atten.)	App	8586
6643	55000006	No	971970259	1997	A	31	ROR on right and struck "end of the bridge" head on approach (diag shows this, clearly no app GR in diag)	BR	Yes (Atten.)	App	1400
67504	67000006	No	670151	2000	A	31	"Swerved to miss deer; struck corner of bridge" (diag shows strike near end of bridge rail)	BR	Yes (Atten.)	App	415
7122	67000008	No	930040239	1993	A	31	Struck bridge rail (diag shows a head-on strike to end of rail)	BR	Yes (Atten.)	App	385
23512	23000012	No	923320204	1992	A	31	Slippery road, lost control, "struck bridge" (diag shows a side-impact direct strike on rail end)	BR	Yes (Atten.)	Dep	760
92760	67000008	No	912320191	1991	A	31	"Driver struck bridge railing on opposite side of road" (diagram shows a head-on strike to end of rail on opposite side and vehicle continuing off the roadway)	BR	Yes (Atten.)	Dep	200
L2146	67000016	No	961860211	1996	A	37	ROR and struck bank of waterway (diag shows veh went to left between two bridges)	Roadside	Yes (Redir.)	App	310
89225	50000016	No	1970205	2000	A	51	Swerved to miss deer, crossed centerline, ROR into ditch and rolled over; ahead of bridge but no object struck	Roadside	Yes (Redir.)	Dep	380
92417	83000005	No	960710083	1996	B	30	Lost control, ROR and into ditch on left side ahead of bridge, striking several trees and coming to rest near river	Roadside	Yes (Redir.)	Dep	560

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
42536	42000005	No	900010205	1990	B	30	ROR and struck tree approx 100 ft from bridge (no diag)	Roadside	Yes (Redir.)	Unsure	425
19529	19000068	No	942310046	1994	B	31	"Hit bridge abutment (one lane bridge)" (diag shows head-on strike with end of BR on approach side)	BR	Yes (Atten.)	App	5200
2520	2000051	No	950690128	1995	B	31	Swerved to avoid deer, lost control, left roadway, struck snow bank, "struck bridge" and overturned down embankment into creek (diag shows strike with end of BR on app side….clearly no app GR in diag)	BR	Yes (Redir.)	App	16500
L2146	67000016	No	923020220	1992	B	31	Swerved to miss deer, "ran head on into the bridge rail on right side…vehicle was totaled" (diag showed head-on end strike with rail)	BR	Yes (Atten.)	App	310
55508	55000015	No	920220081	1992	B	31	Lost control on slippery road, "hit bridge" (appears to be rail side-strike from diag) stopped near road edge	BR	Yes (Redir.)	Dep	800
67501	67000001	No	991590215	1999	B	31	"Tractor hit bridge guardrail throwing veh out of control then rolled over the bridge rail and into creek" (diag show hitting bridge rail and ROR towards departure end of rail)	BR	Yes (Redir.)	Dep	510
9939	23000029	No	90158	2000	B	41	"Struck end of bridge"; (diag shows direct strike on end of rail)	BR	Yes (Atten.)	App	50
25522	25000007	No	21740176	2002	B	51	ROR and overturned in ditch near bridge, but no object struck	Roadside	Yes (Redir.)	App	455

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
55543	55000003	No	740218	2000	B	51	ROR near end of bridge rail on departure side, no object struck	Roadside	Yes (Redir.)	Dep	500
23545	23000002	No	890490516	1989	C	26	Lost control on icy bridge, ROR to right, struck end of bridge on approach (diag shows strike on end of BR on approach side, no GR shown)	BR	Yes (Atten.)	App	1400
42522	42000009	No	931270218	1993	C	31	ROR and "hit bridge" (no diag, although other portions of the report suggest approach side strike)	BR	Yes (Atten.)	App	245
L2106	67000007	No	930860150	1993	C	31	ROR and into ditch; recovered out of ditch and "struck the bridge" (diag shows driver striking end of bridge and redirecting back onto road)	BR	Yes (Atten.)	App	1100
L2135	67000013	No	991240286	1999	C	31	"veh in ditch, bridge rail completely wiped out" (diag shows that veh crossed road and hit BR (sideswipe) on opposite side, went into ditch just past opposite approach side)	BR	Yes (Redir.)	App	1200
19529	19000068	No	882700230	1988	C	31	No description. Diagram shows head-on collision with left side BR on approach. Difficult to tell from diag what is actually struck	BR	Yes (Atten.)	Dep	5200
55518	55000020	No	20570174	2002	C	31	Lost control on ice, "vehicle struck bridge head-on", (no diagram included)	BR	Yes (Atten.)	Unsure	600
23512	23000012	No	933540349	1993	C	51	Snowy roadway, ROR "just before the bridge" (diagram shows nearly missing rail), overturned and landed in creek	Roadside	Yes (Redir.)	Dep	760
L1705	42000009	No	921500001	1992	K	30	ROR on the right, went into ditch, sideswiped one tree and struck another head-on, vehicle engulfed in fire (diag shows 177' upstream of bridge on approach)	Roadside	Yes (Redir.)	App	330

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
2103	25000002	No	930440001	1993	K	31	"Driver lost control and struck bridge" (diag shows driver side impact with end of bridge rail on approach side)	BR	Yes (Atten.)	App	820
55508	55000015	No	931130001	1993	K	31	"Driver ROR to left, overcorrected back to right, struck bridge rail with rear of veh (sheared off rear of veh) vaulted down river bank striking trees, coming to rest submerged in the river" (diag shows impact with end of BR on approach side proceeding into river)	BR	Yes (Atten.)	App	800
67538	67000003	No	962060002	1996	K	31	"Swiped bridge guardrail, then went through the guardrail and into the creek, a piece of GR went through the car" (diag shows head-on strike on end of BR on approach - no approach GR)	BR	Yes (Atten.)	App	470
83536	83000027	No	940570336	1994	K	31	"Hit bridge, tore 12' of steel bridge railing off, railing came through cab striking driver, ejected him into creek, car flipped and came to rest in creek" (diag does not show point of impact, but based on the description of the "spearing" it's likely an end hit)	BR	Yes (Atten.)	App	1450
23545	23000002	No	911290209	1991	K	51	ROR near bridge (on approach) on left side (but did not strike), struck ditch, went airborne, overturned (difficult from diag to determine how close vehicle was to bridge when ROR occurred)	Roadside	Yes (Redir.)	Dep	1400
23521	23000021	No	12950096	2001	N	30	Lost control, ROR near bridge and hit tree	Roadside	Yes (Redir.)	Dep	120
2103	25000002	No	13580148	2001	N	31	Too fast around curve, lost control and struck bridge rail, and ROR into ditch	BR	Yes (Redir.)	App	820

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
23567	23000038	No	982160233	1998	N	31	Unknown events leading to collision. Vehicle found after "collision with guardrail on bridge" (diag shows head-on strike with end of bridge rail, no GR)	BR	Yes (Atten.)	App	105
3299	67000003	No	912510175	1991	N	31	Driver fell asleep and struck "corner of bridge" (no diag but other portions of the report suggests approach side collision)	BR	Yes (Atten.)	App	245
4795	83000032	No	891610272	1989	N	31	Lost control, "hit edge of bridge and went into creek"	BR	Yes (Redir.)	App	105
55522	55000025	No	930720120	1993	N	31	Lost control ROR on right on approach, struck "bridge" on approach side, went down embankment into river (diag shows direct strike on end of BR on approach side, no GR)	BR	Yes (Atten.)	App	18900
55535	55000032	No	900510018	1990	N	31	Lost control, ROR, struck end of bridge and into ditch	BR	Yes (Redir.)	App	220
6643	55000006	No	932340125	1993	N	31	"hit guardrail on bridge, veh came to rest approx 135 ft from point of impact" (diag shows impact near leading end of BR, veh stays on road)	BR	Yes (Atten.)	App	1400
L2120	67000009	No	962730012	1996	N	31	Driver struck bridge (no diagram)	BR	Yes (Atten.)	App	440
L2146	67000016	No	962020211	1996	N	31	"Struck bridge, continued east and then ROR into ditch" (diag shows sideswipe of left rail and ROR on left after end of rail)	BR	Yes (Redir.)	App	310
19529	19000068	No	941820229	1994	N	31	Veh crossed bridge, struck "bridge guardrail" on the right breaking it, then continuing striking the "cement approach barriers" then ROR to the right coming to rest on shoulder (diag clearly shows strike on departure side concrete wing-wall connected to BR)	BR	Yes (Redir.)	Dep	5200

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
23545	23000002	No	910750085	1991	N	31	ROR into ditch, turned out of the ditch and "hit the GR and bridge on the left side of the road" (diag shows a side impact direct hit on end of BR but no GR)	BR	Yes (Atten.)	Dep	1400
42546	42000008	No	900940191	1990	N	31	"Struck bridge, minor damage to bridge, veh. totaled, driver uninjured" (diag shows veh ROR on departure side after striking bridge)	BR	Yes (Redir.)	Dep	340
L2136	67000013	No	890760525	1989	N	31	ROR and "hit bridge with right side", no diag	BR	Yes (Atten.)	Unsure	990
83539	83000027	No	950050076	1995	N	34	ROR on curve and "went through GR" (diagram shows bridge nearby, but GR does not appear to be connected to bridge)	Roadside	Yes (Redir.)	App	1200
55543	55000003	No	2710099	2000	N	37	ROR into ditch on left side ahead of bridge and crashed into embankment near river	Roadside	Yes (Redir.)	Dep	500
7211	42000003	No	941380225	1994	N	51	Driver fell asleep and ROR and overturned (from diag it appears to ROR very near bridge)	Roadside	Yes (Redir.)	App	420
25522	25000007	No	901740199	1990	N	51	ROR into ditch and overturned	Roadside	Yes (Redir.)	Dep	455
55023	55000036	No	1650148	2000	C	31	Lost control on wet road, "struck bridge rail" (diag shows angle hit on BR in middle of bridge)	BR	On Bridge	**On Bridge**	4550
19529	19000068	No	911040152	1991	N	31	Lost control on bridge and "struck bridge" (no diag)	BR	On Bridge	**On Bridge**	5200

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Would GR have helped?	Was Crash on Approach or Departure Side?	Pontis AADT
3298	67000003	No	933160297	1993	N	31	"Lost control on icy bridge and hit guardrail" (no diagram)	BR	On Bridge	**On Bridge**	630
5050	67000004	No	960040284	1996	N	31	Driver lost control on snowy curve, and "slid into bridge" (diag shows bridge on curve, driver struck BR nearly head-on on outside of curve)	BR	On Bridge	**On Bridge**	3050
55516	55000007	No	883320225	1988	N	31	Lost control on icy bridge deck, "struck both sides of bridge" (diag doesn't show bridge)	BR	On Bridge	**On Bridge**	940
55522	55000025	No	933090667	1993	N	31	veh skidded on icy bridge deck, "struck bridge curb" (diag shows strike on bridge and redirection)	Curb	On Bridge	**On Bridge**	18900
L2136	67000013	No	920690309	1992	N	31	Slippery road, lost control, "collided with bridge…entire railing was removed" (diag shows rail sideswipe)	BR	On Bridge	**On Bridge**	990

Table F-2. Summary of Crash Reports: Fixed-Object and ROR Crashes Occurring at Bridges WITH Approach Guardrail, 1988 - 2002

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
25508	25000014	Yes	911890032	1991	A	31	Crossed centerline, ROR onto left shoulder ahead of bridge, overcorrected back onto road, struck end of "bridge railing" on left side, rolled on roadway and overturned, veh came to rest on bridge railing (diag shows struck railing on opposite side as approaching)	BR	No (Dep ROR)	Dep	245
50507	50000025	Yes	882610038	1988	A	51	ROR on left prior to bridge (about 150' prior), struck ditch, tree, and went into creek, rolling multiple times (diag shows no GR)	Roadside	No (Dep ROR)	Dep	230
7091	50000006	Yes	23010229	2002	B	25	Driver slid on snow covered bridge deck, spun around, ROR to the right and into ditch striking utility pole (diag shows ROR on right shortly after crossing bridge)	Roadside	No (Dep ROR)	Dep	640
25517	25000066	Yes	001530239	2000	B	26	Swerved to miss animal, ROR onto left ahead of bridge, striking utility sign, tree, then came to rest in creek, submerged (diag shows this, no app GR shown)	Roadside	No (Dep ROR)	Dep	6700
23507	23000001	Yes	882400282	1988	B	31	"Hit guardrail, vehicle skidded along rail for 28 ft, jumped rail and rolled" (diag shows hit on approach GR)	GR	No (Vault)	App	1300
2536	2000009	Yes	20450216	2002	B	31	Lost control and "collided with bridge" (diag shows angle hit on BR near GR/BR connection)	BR/GR	Yes (Atten.)	App	10380
50504	50000001	Yes	970900207	1997	B	31	ROR to the right, took out 18-ft of "guardrail", 4- 6X8 posts, 1 bridge sign and end panel (diag shows ROR and strike on end of bridge, but does not show app GR)	GR	Yes (Atten.)	App	410

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
5289	23000001	Yes	991080111	1999	B	31	lost control "struck bridge, spun around, stopping in opposite lane" (diag shows angle strike on BR/GR connection on approach side)	BR/GR	Yes (Atten.)	App	1300
55519	55000022	Yes	2860335	2000	B	31	Swerved to miss animal, "struck bridge" (diag shows angle hit at GR/BR connection)	BR/GR	Yes (Atten.)	App	25500
55519	55000022	Yes	990110257	1999	B	31	lost control on icy deck, "stuck cement barrier on right, crossed road, struck broadside by oncoming veh, struck bridge guardrail" (diag shows initial strike on BR in center of bridge, second strike on end of BR near GR connection on opposite approach)	BR/GR	Yes (Atten.)	App	25500
6787	67000017	Yes	981150060	1998	B	31	Lost control and "hit the guardrail" (diag shows grazing the end treatment of GR, but no bridge in picture) and proceeded into ditch, through creek and into a fence	GR	No (Short)	App	560
83539	83000027	Yes	951480159	1995	B	31	started to hydroplane, lost control, slid sideways into "bridge guardrail" (diag shows strike on what appears to be a very short section of approach GR)	GR	Yes (Atten.)	App	1200
50517	50000025	Yes	920610125	1992	B	31	Driver ROR and struck "bridge guardrail", (diagram shows end strike on left side GR while approaching)	GR	Yes (Atten.)	Dep	750
25505	25000018	Yes	983130218	1998	B	33	"drove car into guardrail of a bridge" (no diag, but type = 33 and description implies guardrail strike, probably on BCT or other type of end treatment)	GR	Yes (Atten.)	App	7400
2526	02000007	Yes	952650131	1995	B	51	Driver skidded on icy bridge deck, crossed centerline, ROR to the left after crossing bridge and struck tree (diag shows bridge, but no app GR, it appears that driver ROR slightly upstream of where normal section of app GR would have begun)	Roadside	No (Short)	App	8708

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
2519	2000022	Yes	922590283	1992	C	31	Veh slid through T-intersection, "went through GR and came to rest in swamp" (Diag does not show bridge or GR although crash location code is very close to bridge reference point)	GR	No (Vault)	App	8586
55519	55000022	Yes	980260299	1998	C	31	lost control and "contacted guardrail" veh redirected into opposing lanes coming to rest (diag confirms app GR strike)	GR	Yes (Redir.)	App	25500
7148	50000014	Yes	13600097	2001	C	31	ROR, struck "breakaway guardrail for the bridge" (diag shows direct hit on end treatment of approach GR)	GR	Yes (Atten.)	App	1200
19504	19000085	Yes	960900036	1996	C	31	Lost control, "struck bridge/guardrail" (diagram shows what appears to be a strike on GR near rail end on left side and redirection back to road)	GR	Yes (Atten.)	Dep	890
23508	23000001	Yes	893580012	1989	C	31	Driver fell asleep, ROR (diag shows head-on strike on end of BR on left side while approaching, no GR shown)	BR	No (Dep ROR)	Dep	1300
23508	23000001	Yes	990320184	1999	C	31	lost control on icy road on curve, skidded into "bridge rail" on outside of curve (diag shows angle strike on left BR on approach near end)	BR	No (Dep ROR)	Dep	1300
23508	23000001	Yes	990460180	1999	C	31	lost control on curve, "slid into bridge, bounced off and went into ditch and rolled" (diag shows BR strike on bridge, veh went off road on departure side just past bridge)	Roadside	No (Dep ROR)	Dep	1300
55519	55000022	Yes	971020095	1997	C	31	"Struck guardrail fence and then vaulted below the bridge" (diag shows strike on fence, I confirmed this as a fence from photo in Olmsted Co. inspection rept., other corners have GR)	Roadside	No (Dep ROR)	Dep	25500

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
8259	83000057	Yes	920060019	1992	C	34	ROR and went "up and over GR" (struck near end treatment; I can't determine from diag if GR associated with bridge)	GR	No (Vault)	App	2700
2548	2000022	Yes	933230002	1993	K	37	"ROR into ditch, collided with culvert wall, went airborne and landed on its roof" (no bridge shown in diag, but further analysis shows that culvert strike occurred approximately 100' from departure end of bridge)	Roadside	No (Dep ROR)	Dep	5464
18518	18000036	Yes	881800153	1988	N	30	Swerved to miss deer, ROR on right into ditch, hit tree (diag shows ROR ahead of bridge just missing approach GR on right)	Roadside	No (Short)	App	1100
18518	18000036	Yes	990670701	1999	N	31	slid into "bridge rail; after hitting bridge rail, crossed to opposite side and hit bridge rail on opp side" (diag shows angle strike near BR end on approach side, then crossing and hitting left side BR)	BR/GR	Yes (Atten.)	App	1100
2546	2000116	Yes	980120602	1998	N	31	lost control and "struck GR" (diag does not show bridge or GR)	GR	Yes (Redir.)	App	17156
42541	42000033	Yes	913040929	1991	N	31	"started to slide on snowy road and slid into side of bridge" (diag shows sideswipe on BR near end)	BR/GR	Yes (Atten.)	App	3950
55519	55000022	Yes	940850227	1994	N	31	"struck bridge" (diag clearly shows strike near GR/BR connection on approach, redirection back onto bridge)	BR/GR	Yes (Atten.)	App	25500
55519	55000022	Yes	941620139	1994	N	31	swerved to miss oncoming veh, "struck bridge, redirected and hit curb on bridge" (diag shows initial strike on BR end near GR/BR connection)	BR/GR	Yes (Atten.)	App	25500
55519	55000022	Yes	911080167	1991	N	31	"struck GR and slid 106 ft along bridge coming to rest against bridge" (diag shows approach GR strike)	GR	Yes (Redir.)	App	25500

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
7016	50000005	Yes	931850211	1993	N	31	"Hit bridge with right rear, then hit east guardrail with front right, came to rest in ditch" (diagram shows what appears to be very short section of GR attached to bridge rail)	GR	No (Short)	App	210
83539	83000027	Yes	941600143	1994	N	31	"trailer swung out and struck guardrail and then bridge rail on both sides" (diag shows same)	GR	Yes (Redir.)	App	1200
96834	2000116	Yes	3470382	2000	N	31	Lost control on icy road, "hit guardrail" (diag shows hit on bridge-approach GR on left side after crossing bridge)	GR	Yes (Redir.)	App	17156
L3170	19000047	Yes	21060036	2002	N	31	Lost control and "hit the guardrail" (diag shows hit on end of BR on approach, but does not discern between BR and GR although it is confirmed to exist at time of crash)	GR	Yes (Atten.)	App	2250
18524	18000011	Yes	11180221	2001	N	31	Lost control "hitting bridge" (diag shows sideswipe on left side BR near end while approaching, GR shown on both app and dep)	BR/GR	Yes (Atten.)	Dep	1050
2519	2000022	Yes	960560053	1996	N	31	"Struck guardrail, slid along GR, ran into bridge abutment, spun around and off the GR" (diag clearly shows strike on departure-side GR while approaching)	GR	Yes (Redir.)	Dep	8586
25517	25000066	Yes	881130125	1988	N	31	Ran stop sign at T-intersection and "hit bridge-approach guardrail" on opposite side of intersection	GR	Yes (Redir.)	Dep	6700
50504	50000001	Yes	892260077	1989	N	31	Blown tire, lost control, "stuck bridge guardrail and then went into ditch", (no diag. although veh damage pattern suggests collision with right side of veh)	GR	No (Dep ROR)	Dep	410

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
5368	50000029	Yes	940340112	1994	N	31	No description. Diagram shows collision with departure GR	GR	Yes (Redir.)	Dep	2950
83513	83000012	Yes	992700240	1999	N	31	Driver swerved to miss deer and "hit guardrail" (no diagram)	GR	Yes (Redir.)	Unsure	255
7048	50000023	Yes	890360131	1989	N	34	Lost control on bridge, "struck three GR posts breaking them off" (diag shows veh crossing bridge, hitting app GR on left and coming to rest on roadway)	GR	Yes (Redir.)	App	2150
7016	50000005	Yes	881140257	1988	N	35	Lost control on icy bridge deck and ROR on right into ditch striking a fence	Roadside	No (Short)	App	210
2526	02000007	Yes	913460323	1991	N	51	Slid on icy road into snow bank on right just ahead of bridge (diag shows bridge and approach GR, it appears that driver hit snow drifted that had accumulated around the guardrail in which case the GR was or would have been effective for redirecting driver)	GR	Yes (Redir.)	App	8708
8433	19000009	Yes	001810300	2000	N	51	Driver fell asleep, ROR on right ahead of bridge, struck trees and overturned, came to rest in water (diag shows this, bridge is shown but no app GR shown, veh appears to ROR slightly upstream from where GR would start, ref pt is about 80-ft upstream of bridge ID)	Roadside	No (Short)	App	3300
92730	2000024	Yes	923240343	1992	N	51	Skidded on ice, ROR into ditch and overturned (diag showed bridge nearby)	Roadside	No (Dep ROR)	Dep	1000

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
2560	2000014	Yes	940820565	1994	B	31	slid on icy RR overpass, "went over median, striking wall of bridge in opposite lanes" (diag confirms this)	BR	On Bridge	**On Bridge**	20076
55519	55000022	Yes	953040220	1995	B	31	Lost control while passing, "struck bridge on opposite side" crossed back and ROR near bridge" (diag shows sideswipe on BR and ROR just past end of BR on departure side)	BR	On Bridge	**On Bridge**	25500
18523	18000021	Yes	940090192	1994	C	31	Blizzard conditions, driver lost control and "hit the bridge" (diag shows a sideswipe on the bridge rail)	BR	On Bridge	**On Bridge**	530
2523	2000002	Yes	990040503	1999	C	31	lost control on icy road, "struck right cement guardrail, bounced off and struck left cement guardrail" (diag shows same)	BR	On Bridge	**On Bridge**	9103
2549	2000018	Yes	20640038	2002	C	31	Lost control and "hit cement barrier on side of road, bounced and hit barrier on other side" (diag doesn't show BR or GR)	BR	On Bridge	**On Bridge**	14479
50576	50000008	Yes	3520262	2000	C	31	"Drove through snow drift, causing veh to hit concrete guard rail on bridge" (no diagram)	BR	On Bridge	**On Bridge**	770
19504	19000085	Yes	893580035	1989	N	31	Swerved and "struck bridge" no diag to confirm	BR	On Bridge	**On Bridge**	890
23514	23000001	Yes	90088	2000	N	31	"Struck Bridge GR"; (diag shows angle hit on BR while on bridge)	BR	On Bridge	**On Bridge**	900
2536	2000009	Yes	912040171	1991	N	31	Became inattentive while crossing bridge, drifted right and side swiped bridge (diag shows swipe with BR on bridge)	BR	On Bridge	**On Bridge**	10380
2545	2000116	Yes	980440065	1998	N	31	veh 1 spun on icy bridge deck, "comes to stop upon hitting guardrail, veh 2 stops and rear ended by veh 3" (diag shows striking BR on bridge (not GR))	BR	On Bridge	**On Bridge**	17156

Bridge Num	Route	Did Bridge Have App. GR?	Acc Num	Crash Year	Sev	Type	Police Description	Initial Object Struck	Did GR help?	Was Crash on Approach or Departure Side?	Pontis AADT
2549	2000018	Yes	3630748	2000	N	31	Lost control on bridge deck, "struck side of bridge" (diag shows angle hit on left side BR near end upon departing bridge)	BR	On Bridge	**On Bridge**	14479
2560	2000014	Yes	940820275	1994	N	31	crested hill over RR overpass, "slid into center curb median, veered into bridge GR hitting it head-on" (diag doesn't show collision details)	Curb	On Bridge	**On Bridge**	20076
5368	50000029	Yes	890730616	1989	N	31	Veh spun and "struck bridge" (diag shows sideswipe on BR while on bridge, no GR shown)	BR	On Bridge	**On Bridge**	2950
55519	55000022	Yes	973330238	1997	N	31	swerved to miss vehicle, "collided with wall of bridge" (diag shows sideswipe with BR on bridge)	BR	On Bridge	**On Bridge**	25500
67524	67000004	Yes	930410103	1993	N	31	Driver hit snow drift on road, veh slid and struck "bridge railing" (diag shows huge drift from behind railing onto road, veh appears to hit railing on bridge)	BR	On Bridge	**On Bridge**	1450
7048	50000023	Yes	983650208	1998	N	31	skidded on icy road, struck "cement guardrail on bridge, bounced back hitting opposite guardrail, bounced back stopping at opposite guardrail" (diag doesn't show BR or GR)	BR	On Bridge	**On Bridge**	2150
2549	02000018	Yes	010260770	2001	N	32	Lost control of veh and hit "cement barrier" on bridge (diag shows striking BR while on bridge)	BR	On Bridge	**On Bridge**	14479
6518	18000003	Yes	970490305	1997	N	51	Semi rolled on roadway	BR	On Bridge	**On Bridge**	8600
19511	19000042	Yes	003120577	2000	N	51	Lost control on icy bridge, struck curb and rolled on roadway (diag shows this, no bridge or GR shown)	Curb	On Bridge	**On Bridge**	39500

APPENDIX G

Explanation of Minnesota Procedure for Coding Crashes with Bridge Components and Guardrail.

Conversations with Mn/DOT staff[1] provided a straightforward explanation for the bridge-crash coding ambiguity that currently exists in the Minnesota crash database. Prior to 2003, a separate code was included on the crash report to indicate the type of fixed object struck. On crash report forms from 1988–1991, FIXED OBJECT TYPE 13 was used to indicate "bridge/pier (include protective guardrail)". In 1992, a slight modification was made to the description for code 13, which was changed to "bridge/pier/guardrail" and remained as such until after 2002. From 1988–2002 FIXED OBJECT TYPE 14 was used for "other guardrail." The use of FIXED OBJECT TYPES 13 and 14 provided distinction between components of a bridge (including approach guardrail) and guardrail that was not connected to a bridge.

In 2003, the Minnesota crash reporting form experienced dramatic changes in format and coding. FIXED OBJECT TYPES 13 and 14 were eliminated and changed to FIXED OBJECT TYPES 31 "bridge piers" and 34 "guardrail." The fundamental purpose of this change was to code all guardrail collisions (including bridge-approach guardrail and other guardrail) together. All bridge collisions (other than approach guardrail) would be coded by TYPE 31.

Perhaps the most significant change was the elimination of FIXED OBJECT TYPES 13 and 14 from the Minnesota crash database. Crashes previously coded as 13 (bridge/pier/guardrail) were changed to 31 (bridge pier). Similarly, crashes previously coded as TYPE 14 (other guardrail) were changed to 34 (guardrail). Because the analysis performed here only included crashes that occurred prior to the major reporting system changes in 2003, it can be assumed that approach guardrail or bridge rail crashes will be currently coded in the Minnesota crash database as TYPE 31 unless a coding error occurred in the field or during entry into the database.

[1] Primary conversation with Loren Hill, Mn/DOT, 4/19/05

APPENDIX H

Crash Frequencies and Costs by ADT Category, Crash Severity, and Guardrail Presence

Table H-1. Bridge-Crash Costs vs. Guardrail Presence – All Bridges.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	22	46.81	$4,300	$94,600
	C Injury	9	19.15	$29,000	$261,000
	B Injury	13	27.66	$59,000	$767,000
	A Injury	2	4.26	$270,000	$540,000
	Fatal	1	2.13	$3,500,000	$3,500,000
	Total Crashes	47		Total Cost	$5,162,600
	Total Bridges	155		Cost Per Crash	$109,843
	Est. Traffic 1988-2002	3,152,527,769		Cost Per Year	$344,173
	Crashes per 10^8 veh	1.491		Cost Per Bridge	$33,307
				Cost/Br/Year	$2,220
				Cost/10^8 veh	$163,761
Bridges WITHOUT Approach Guardrail	Property Damage	18	36.73	$4,300	$77,400
	C Injury	7	14.29	$29,000	$203,000
	B Injury	10	20.41	$59,000	$590,000
	A Injury	8	16.33	$270,000	$2,160,000
	Fatal	6	12.24	$3,500,000	$21,000,000
	Total Crashes	49		Total Cost	$24,030,400
	Total Bridges	243		Cost Per Crash	$490,416
	Est. Traffic 1988-2002	1,327,656,551		Cost Per Year	$1,602,027
	Crashes per 10^8 veh	3.691		Cost Per Bridge	$98,891
				Cost/Br/Year	$6,593
				Cost/10^8 veh	$1,809,986

Table H-2. Bridge-Crash Costs vs. Guardrail Presence – ADT < 150.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	0	-	$4,300	$0
	C Injury	0	-	$29,000	$0
	B Injury	0	-	$59,000	$0
	A Injury	0	-	$270,000	$0
	Fatal	0	-	$3,500,000	$0
	Total Crashes	0		Total Cost	$0
	Total Bridges	6		Cost Per Crash	$0
	Est. Traffic 1988-2002	2,888,633		Cost Per Year	$0
	Crashes per 10^8 veh	0		Cost Per Bridge	$0
				Cost/Br/Year	$0
				Cost/10^8 veh	$0
Bridges WITHOUT Approach Guardrail	Property Damage	3	75.00	$4,300	$12,900
	C Injury	0	0.00	$29,000	$0
	B Injury	1	25.00	$59,000	$59,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	4		Total Cost	$71,900
	Total Bridges	63		Cost Per Crash	$17,975
	Est. Traffic 1988-2002	27,224,725		Cost Per Year	$4,793
	Crashes per 10^8 veh	14.693		Cost Per Bridge	$1,141
				Cost/Br/Year	$76
				Cost/10^8 veh	$264,098

Table H-3. Bridge-Crash Costs vs. Guardrail Presence – ADT 150-299.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	3	60.00	$4,300	$12,900
	C Injury	0	0.00	$29,000	$0
	B Injury	0	0.00	$59,000	$0
	A Injury	2	40.00	$270,000	$540,000
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	5		Total Cost	$552,900
	Total Bridges	14		Cost Per Crash	$110,580
	Est. Traffic 1988-2002	16,840,950		Cost Per Year	$36,860
	Crashes per 10^8 veh	29.690		Cost Per Bridge	$39,493
				Cost/Br/Year	$2,633
				Cost/10^8 veh	$3,283,069
Bridges WITHOUT Approach Guardrail	Property Damage	2	50.00	$4,300	$8,600
	C Injury	1	25.00	$29,000	$29,000
	B Injury	0	0.00	$59,000	$0
	A Injury	1	25.00	$270,000	$270,000
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	4		Total Cost	$307,600
	Total Bridges	50		Cost Per Crash	$76,900
	Est. Traffic 1988-2002	58,748,895		Cost Per Year	$20,507
	Crashes per 10^8 veh	6.809		Cost Per Bridge	$6,152
				Cost/Br/Year	$410
				Cost/10^8 veh	$523,584

Table H-4. Bridge-Crash Costs vs. Guardrail Presence – ADT 300-399.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	0	-	$4,300	$0
	C Injury	0	-	$29,000	$0
	B Injury	0	-	$59,000	$0
	A Injury	0	-	$270,000	$0
	Fatal	0	-	$3,500,000	$0
	Total Crashes	0		Total Cost	$0
	Total Bridges	7		Cost Per Crash	$0
	Est. Traffic 1988-2002	12,270,654		Cost Per Year	$0
	Crashes per 10^8 veh	0.000		Cost Per Bridge	$0
				Cost/Br/Year	$0
				Cost/10^8 veh	$0
Bridges WITHOUT Approach Guardrail	Property Damage	2	33.33	$4,300	$8,600
	C Injury	0	0.00	$29,000	$0
	B Injury	1	16.67	$59,000	$59,000
	A Injury	2	33.33	$270,000	$540,000
	Fatal	1	16.67	$3,500,000	$3,500,000
	Total Crashes	6		Total Cost	$4,107,600
	Total Bridges	22		Cost Per Crash	$684,600
	Est. Traffic 1988-2002	39,815,282		Cost Per Year	$273,840
	Crashes per 10^8 veh	15.070		Cost Per Bridge	$186,709
				Cost/Br/Year	$12,447
				Cost/10^8 veh	$10,316,642

Table H-5. Bridge-Crash Costs vs. Guardrail Presence – ADT 400-749.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	1	25.00	$4,300	$4,300
	C Injury	0	0.00	$29,000	$0
	B Injury	3	75.00	$59,000	$177,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	4		Total Cost	$181,300
	Total Bridges	25		Cost Per Crash	$45,325
	Est. Traffic 1988-2002	71,683,848		Cost Per Year	$12,087
	Crashes per 10^8 veh	5.580		Cost Per Bridge	$7,252
				Cost/Br/Year	$483
				Cost/10^8 veh	$252,916
Bridges WITHOUT Approach Guardrail	Property Damage	4	30.77	$4,300	$17,200
	C Injury	1	7.69	$29,000	$29,000
	B Injury	5	38.46	$59,000	$295,000
	A Injury	2	15.38	$270,000	$540,000
	Fatal	1	7.69	$3,500,000	$3,500,000
	Total Crashes	13		Total Cost	$4,381,200
	Total Bridges	51		Cost Per Crash	$337,015
	Est. Traffic 1988-2002	132,209,352		Cost Per Year	$292,080
	Crashes per 10^8 veh	9.833		Cost Per Bridge	$85,906
				Cost/Br/Year	$5,727
				Cost/10^8 veh	$3,313,835

Table H-6. Bridge-Crash Costs vs. Guardrail Presence – ADT 750-999.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	0	0.00	$4,300	$0
	C Injury	1	50.00	$29,000	$29,000
	B Injury	1	50.00	$59,000	$59,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	2		Total Cost	$88,000
	Total Bridges	15		Cost Per Crash	$44,000
	Est. Traffic 1988-2002	64,828,202		Cost Per Year	$5,867
	Crashes per 10^8 veh	3.085		Cost Per Bridge	$5,867
				Cost/Br/Year	$391
				Cost/10^8 veh	$135,743
Bridges WITHOUT Approach Guardrail	Property Damage	1	16.67	$4,300	$4,300
	C Injury	1	16.67	$29,000	$29,000
	B Injury	1	16.67	$59,000	$59,000
	A Injury	1	16.67	$270,000	$270,000
	Fatal	2	33.33	$3,500,000	$7,000,000
	Total Crashes	6		Total Cost	$7,362,300
	Total Bridges	12		Cost Per Crash	$1,227,050
	Est. Traffic 1988-2002	51,373,731		Cost Per Year	$490,820
	Crashes per 10^8 veh	11.679		Cost Per Bridge	$613,525
				Cost/Br/Year	$40,902
				Cost/10^8 veh	$14,330,865

Table H-7. Bridge-Crash Costs vs. Guardrail Presence – ADT 1,000-1,499.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	5	41.67	$4,300	$21,500
	C Injury	4	33.33	$29,000	$116,000
	B Injury	3	25.00	$59,000	$177,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	12		Total Cost	$314,500
	Total Bridges	21		Cost Per Crash	$26,208
	Est. Traffic 1988-2002	132,194,176		Cost Per Year	$20,967
	Crashes per 10^8 veh	9.078		Cost Per Bridge	$14,976
				Cost/Br/Year	$998
				Cost/10^8 veh	$237,908
Bridges WITHOUT Approach Guardrail	Property Damage	4	44.44	$4,300	$17,200
	C Injury	3	33.33	$29,000	$87,000
	B Injury	0	0.00	$59,000	$0
	A Injury	1	11.11	$270,000	$270,000
	Fatal	1	11.11	$3,500,000	$3,500,000
	Total Crashes	9		Total Cost	$3,874,200
	Total Bridges	17		Cost Per Crash	$430,467
	Est. Traffic 1988-2002	104,403,154		Cost Per Year	$258,280
	Crashes per 10^8 veh	8.620		Cost Per Bridge	$227,894
				Cost/Br/Year	$15,193
				Cost/10^8 veh	$3,710,807

Table H-8. Bridge-Crash Costs vs. Guardrail Presence – ADT 1,500-4,999.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	5	83.33	$4,300	$21,500
	C Injury	1	16.67	$29,000	$29,000
	B Injury	0	0.00	$59,000	$0
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	6		Total Cost	$50,500
	Total Bridges	29		Cost Per Crash	$8,417
	Est. Traffic 1988-2002	385,498,778		Cost Per Year	$3,367
	Crashes per 10^8 veh	1.556		Cost Per Bridge	$1,741
				Cost/Br/Year	$116
				Cost/10^8 veh	$13,100
Bridges WITHOUT Approach Guardrail	Property Damage	0	0.00	$4,300	$0
	C Injury	0	0.00	$29,000	$0
	B Injury	0	0.00	$59,000	$0
	A Injury	0	0.00	$270,000	$0
	Fatal	1	100.00	$3,500,000	$3,500,000
	Total Crashes	1		Total Cost	$3,500,000
	Total Bridges	16		Cost Per Crash	$3,500,000
	Est. Traffic 1988-2002	185,931,837		Cost Per Year	$233,333
	Crashes per 10^8 veh	0.538		Cost Per Bridge	$218,750
				Cost/Br/Year	$14,583
				Cost/10^8 veh	$1,882,410

Table H-9. Bridge-Crash Costs vs. Guardrail Presence – ADT 5,000-9,999.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	3	37.50	$4,300	$12,900
	C Injury	1	12.50	$29,000	$29,000
	B Injury	3	37.50	$59,000	$177,000
	A Injury	0	0.00	$270,000	$0
	Fatal	1	12.50	$3,500,000	$3,500,000
	Total Crashes	8		Total Cost	$3,718,900
	Total Bridges	20		Cost Per Crash	$464,863
	Est. Traffic 1988-2002	719,418,793		Cost Per Year	$247,927
	Crashes per 10^8 veh	1.112		Cost Per Bridge	$185,945
				Cost/Br/Year	$12,396
				Cost/10^8 veh	$516,931
Bridges WITHOUT Approach Guardrail	Property Damage	1	25.00	$4,300	$4,300
	C Injury	1	25.00	$29,000	$29,000
	B Injury	1	25.00	$59,000	$59,000
	A Injury	1	25.00	$270,000	$270,000
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	4		Total Cost	$362,300
	Total Bridges	5		Cost Per Crash	$90,575
	Est. Traffic 1988-2002	168,774,233		Cost Per Year	$24,153
	Crashes per 10^8 veh	2.370		Cost Per Bridge	$72,460
				Cost/Br/Year	$4,831
				Cost/10^8 veh	$214,665

Table H-10. Bridge-Crash Costs vs. Guardrail Presence – ADT > 10,000.

	Severity	Crashes 1988-2002	% of Total	Cost per Crash	Total Cost
Bridges WITH Approach Guardrail	Property Damage	5	50.00	$4,300	$21,500
	C Injury	2	20.00	$29,000	$58,000
	B Injury	3	30.00	$59,000	$177,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	10		Total Cost	$256,500
	Total Bridges	18		Cost Per Crash	$25,650
	Est. Traffic 1988-2002	1,746,903,736		Cost Per Year	$17,100
	Crashes per 10^8 veh	0.572		Cost Per Bridge	$14,250
				Cost/Br/Year	$950
				Cost/10^8 veh	$14,683
Bridges WITHOUT Approach Guardrail	Property Damage	1	50.00	$4,300	$4,300
	C Injury	0	0.00	$29,000	$0
	B Injury	1	50.00	$59,000	$59,000
	A Injury	0	0.00	$270,000	$0
	Fatal	0	0.00	$3,500,000	$0
	Total Crashes	2		Total Cost	$63,300
	Total Bridges	7		Cost Per Crash	$31,650
	Est. Traffic 1988-2002	561,177,908		Cost Per Year	$4,220
	Crashes per 10^8 veh	0.356		Cost Per Bridge	$9,043
				Cost/Br/Year	$603
				Cost/10^8 veh	$11,280

APPENDIX I

Benefit/Cost Computations

Table I-1. Bridge-Crash Costs from 1988-2002 Separated by ADT Range and Guardrail Presence.

	Total Crashes 1988-2002		Bridges		Total Traffic 1988-2002		Total Cost of Crashes 1988-2002		Crashes per 10^8 veh 1988-2002		Crash Cost per 10^8 veh 1988-2002	
ADT Range	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR
<150	4	0	63	6	27,224,725	2,888,633	$71,900	$0	14.69253	0.00000	$264,098	$0
150-399	10	5	72	21	96,561,610	29,111,604	$4,415,200	$552,900	10.35608	17.17528	$4,572,418	$1,899,243
400-749	13	4	51	25	132,209,352	71,683,848	$4,381,200	$181,300	9.83289	5.58006	$3,313,835	$252,916
750-999	6	2	12	15	51,373,731	64,828,202	$7,362,300	$88,000	11.67912	3.08508	$14,330,865	$135,743
1,000-1,499	9	12	17	21	104,403,154	132,194,176	$3,874,200	$314,500	8.62043	9.07756	$3,710,807	$237,908
1,500-4,999	1	6	16	29	185,931,837	385,498,778	$3,500,000	$50,500	0.53783	1.55643	$1,882,410	$13,100
5,000-9,999	4	8	5	20	168,774,233	719,418,793	$362,300	$3,718,900	2.37003	1.11201	$214,665	$516,931
10,000<	2	10	7	18	561,177,908	1,746,903,736	$63,300	$256,500	0.35639	0.57244	$11,280	$14,683
All	49	47	243	155	1,327,656,551	3,152,527,769	$24,030,400	$5,162,600	3.69071	1.49087	$1,809,986	$163,761

Table I-2. Bridge-Crash Costs from 1988-2002 Separated by Threshold ADT and Guardrail Presence.

	Total Crashes 1988-2002		Bridges		Total Traffic 1988-2002		Total Cost of Crashes 1988-2002		Crashes per 10^8 veh 1988-2002		Crash Cost per 10^8 veh 1988-2002	
ADT Threshold	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR	No GR	GR
<150	4	0	63	6	27,224,725	2,888,633	$71,900	$0	14.69253	0.00000	$264,098	$0
<400	14	5	135	21	123,786,335	32,000,236	$4,487,100	$552,900	11.30981	15.62488	$3,624,875	$1,727,800
<750	27	9	186	15	255,995,687	103,684,084	$8,868,300	$734,200	10.54705	8.68021	$3,464,238	$708,113
<1,000	33	11	198	21	307,369,419	168,512,286	$16,230,600	$822,200	10.73627	6.52771	$5,280,486	$487,917
<1,500	42	23	215	29	411,772,572	300,706,462	$20,104,800	$1,136,700	10.19981	7.64866	$4,882,501	$378,010
<5,000	43	29	231	20	597,704,410	686,205,240	$23,604,800	$1,187,200	7.19419	4.22614	$3,949,243	$173,009
<10,000	47	37	236	18	766,478,643	1,405,624,033	$23,967,100	$4,906,100	6.13194	2.63228	$3,126,910	$349,034
All	49	47	243	155	1,327,656,551	3,152,527,769	$24,030,400	$5,162,600	3.69071	1.49087	$1,809,986	$163,761

Table I-3. 30-year Cumulative Traffic Forecasts and Estimated Crash Benefits at Bridges Without Approach Guardrail Separated by ADT Range (boldface indicates "benefit" used in B/C ratio).

ADT Range	30 year cumulative traffic, assuming no growth (w/o GR)	30 year cumulative traffic, assuming 2004 growth rates (w/o GR)	30 year cumulative traffic, assuming 2% annual growth (w/o GR)	Estimated 30 year crash costs for bridges w/o guardrail, assuming no growth	Estimated 30 year crash costs for bridges w/o guardrail, assuming 2004 growth rates	Estimated 30 year crash costs for bridges w/o guardrail, assuming 2% annual growth	**Estimated 30 year crash cost per bridge without approach guardrail, assuming no growth**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2004 growth rates**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2% annual growth**
<150	59,554,131	72,219,261	80,533,223	$157,281	$190,730	$212,686.77	**$2,497**	**$3,027**	**$3,376**
150-399	211,124,560	255,758,470	285,497,262	$9,653,496	$11,694,345	$13,054,126.91	**$134,076**	**$162,421**	**$181,307**
400-749	289,424,401	351,660,179	391,379,734	$9,591,048	$11,653,439	$12,969,679.21	**$188,060**	**$228,499**	**$254,307**
750-999	113,331,977	140,102,921	153,255,354	$16,241,452	$20,077,960	$21,962,817.57	**$1,353,454**	**$1,673,163**	**$1,830,235**
1,000-1,499	229,497,320	281,466,092	310,342,182	$8,516,204	$10,444,665	$11,516,200.78	**$500,953**	**$614,392**	**$677,424**
1,500-4,999	409,188,018	503,152,936	553,332,398	$7,702,597	$9,471,403	$10,415,985.89	**$481,412**	**$591,963**	**$650,999**
5,000-9,999	375,570,639	473,275,639	507,872,647	$806,220	$1,015,959	$1,090,227.20	**$161,244**	**$203,192**	**$218,045**
10,000<	1,244,972,525	1,558,089,982	1,683,538,134	$140,431	$175,750	$189,900.50	**$20,062**	**$25,107**	**$27,129**
All	2,932,663,571	3,635,725,478	3,965,750,934	$53,080,805	$65,806,128	$71,779,543.59	**$218,440**	**$270,807**	**$295,389**

Table I-4. 30-year Cumulative Traffic Forecasts and Estimated Crash Benefits at Bridges Without Approach Guardrail Separated by ADT Threshold (boldface indicates "benefit" used in B/C ratio).

ADT Threshold	30 year cumulative traffic, assuming no growth (w/o GR)	30 year cumulative traffic, assuming 2004 growth rates (w/o GR)	30 year cumulative traffic, assuming 2% annual growth (w/o GR)	Estimated 30 year crash costs for bridges w/o guardrail, assuming no growth	Estimated 30 year crash costs for bridges w/o guardrail, assuming 2004 growth rates	Estimated 30 year crash costs for bridges w/o guardrail, assuming 2% annual growth	**Estimated 30 year crash cost per bridge without approach guardrail, assuming no growth**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2004 growth rates**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2% annual growth**
<150	59,554,131	72,219,261	80,533,223	$157,281	$190,730	$212,686.77	**$2,497**	**$3,027**	**$3,376**
<400	270,678,691	327,977,731	366,030,486	$9,811,764	$11,888,783	$13,268,147.84	**$72,680**	**$88,065**	**$98,283**
<750	560,103,092	679,637,910	757,410,220	$19,403,304	$23,544,275	$26,238,493.00	**$104,319**	**$126,582**	**$141,067**
<1,000	673,435,068	819,740,831	910,665,573	$35,560,646	$43,286,302	$48,087,570.69	**$179,599**	**$218,618**	**$242,867**
<1,500	902,932,388	1,101,206,922	1,221,007,755	$44,085,683	$53,766,439	$59,615,715.94	**$205,050**	**$250,076**	**$277,282**
<5,000	1,312,120,407	1,604,359,858	1,774,340,153	$51,818,824	$63,360,071	$70,073,005.59	**$224,324**	**$274,286**	**$303,346**
<10,000	1,687,691,045	2,077,635,497	2,282,212,800	$52,772,586	$64,965,799	$71,362,748.22	**$223,613**	**$275,279**	**$302,385**
All	2,932,663,571	3,635,725,478	3,965,750,934	$53,080,805	$65,806,128	$71,779,543.59	**$218,440**	**$270,807**	**$295,389**

Table I-5. 30-year Costs per Bridge With Approach Guardrail and Associated Benefit/Cost Ratio by ADT Range (boldface indicates "cost" used in B/C ratio).

ADT Range	Min. Cost for Installing and Maintaining Approach Guardrail at a Bridge (assume: 30-year life-cycle and installation at all 4 corners)	Max. Cost for Installing and Maintaining Approach Guardrail at a Bridge (assume: 30-year life-cycle and installation at all 4 corners)	30-year crash cost per bridge with approach guardrail – assuming no growth	30-year crash cost per bridge with approach guardrail – assuming 2004 growth rates	30-year crash cost per bridge with approach guardrail – assuming 2% annual growth	B/C – No growth		B/C – 2004 growth rates		B/C – 2% annual growth	
						Min	Max	Min	Max	Min	Max
<150	**$27,100**	**$45,000**	**$0**	**$0**	**$0**	0.06	0.09	0.07	0.11	0.08	0.12
150-399	**$27,100**	**$45,000**	**$55,691**	**$67,465**	**$75,310**	1.33	1.62	1.44	1.72	1.51	1.77
400-749	**$27,100**	**$45,000**	**$14,353**	**$17,439**	**$19,409**	3.17	4.54	3.66	5.13	3.95	5.47
750-999	**$27,100**	**$45,000**	**$12,820**	**$15,848**	**$17,336**	23.41	33.90	27.50	38.96	29.36	41.19
1,000-1,499	**$27,100**	**$45,000**	**$32,117**	**$39,390**	**$43,431**	6.50	8.46	7.28	9.24	7.66	9.60
1,500-4,999	**$27,100**	**$45,000**	**$3,350**	**$4,120**	**$4,530**	9.96	15.81	12.05	18.96	13.14	20.58
5,000-9,999	**$27,100**	**$45,000**	**$388,288**	**$489,302**	**$525,070**	0.37	0.39	0.38	0.39	0.38	0.39
10,000<	**$27,100**	**$45,000**	**$26,114**	**$32,682**	**$35,314**	0.28	0.38	0.32	0.42	0.34	0.43
All	**$27,100**	**$45,000**	**$19,764**	**$24,502**	**$26,726**	3.37	4.66	3.90	5.25	4.12	5.49

Table I-6. 30-year Costs per Bridge With Approach Guardrail and Associated Benefit/Cost Ratio by ADT Threshold (boldface indicates "cost" used in B/C ratio).

ADT Threshold	Min. Cost for Installing and Maintaining Approach Guardrail at a Bridge (assume: 30-year life-cycle and installation at all 4 corners)	Max. Cost for Installing and Maintaining Approach Guardrail at a Bridge (assume: 30-year life-cycle and installation at all 4 corners)	30-year crash cost per bridge with approach guardrail – assuming no growth	30-year crash cost per bridge with approach guardrail – assuming 2004 growth rates	30-year crash cost per bridge with approach guardrail – assuming 2% annual growth	B/C – No growth		B/C – 2004 growth rates		B/C – 2% annual growth	
						Min	Max	Min	Max	Min	Max
<150	**$27,100**	**$45,000**	**$0**	**$0**	**$0**	0.06	0.09	0.07	0.11	0.08	0.12
<400	**$27,100**	**$45,000**	**$34,643**	**$41,976**	**$46,846**	0.91	1.18	1.01	1.27	1.07	1.33
<750	**$27,100**	**$45,000**	**$21,323**	**$25,874**	**$28,835**	1.57	2.15	1.79	2.39	1.91	2.52
<1,000	**$27,100**	**$45,000**	**$16,595**	**$20,200**	**$22,441**	2.92	4.11	3.35	4.62	3.60	4.90
<1,500	**$27,100**	**$45,000**	**$15,875**	**$19,361**	**$21,468**	3.37	4.77	3.89	5.38	4.17	5.71
<5,000	**$27,100**	**$45,000**	**$9,827**	**$12,016**	**$13,289**	4.09	6.07	4.81	7.01	5.20	7.51
<10,000	**$27,100**	**$45,000**	**$24,960**	**$30,727**	**$33,753**	3.20	4.30	3.64	4.76	3.84	4.97
All	**$27,100**	**$45,000**	**$19,764**	**$24,502**	**$26,726**	3.37	4.66	3.90	5.25	4.12	5.49

Table I-7. Revised Benefit/Cost Ratio Based on ADT 150-299 and ADT 300-399.

ADT Range	Bridges w/o GR	**Estimated 30 year crash cost per bridge without approach guardrail, assuming no growth**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2004 growth rates**	**Estimated 30 year crash cost per bridge without approach guardrail, assuming 2% annual growth**	**30-year crash cost per bridge with approach guardrail – assuming no growth**	**30-year crash cost per bridge with approach guardrail – assuming 2004 growth rates**	**30-year crash cost per bridge with approach guardrail – assuming 2% annual growth**	B/C – No growth		B/C – 2004 growth rates		B/C – 2% annual growth	
								Min	Max	Min	Max	Min	Max
150-299	50	**$13,440**	**$16,250**	**$18,174**	**$84,273**	**$101,895**	**$113,960**	0.10	0.12	0.11	0.13	0.11	0.13
300-399	22	**$388,186**	**$471,636**	**$524,931**	**$0**	**$0**	**$0**	8.63	14.32	10.48	17.40	11.67	19.37
<150	63	**$2,497**	**$3,027**	**$3,376**	**$0**	**$0**	**$0**	0.06	0.09	0.07	0.11	0.08	0.12
<300	113	**$7,340**	**$8,883**	**$9,926**	**$46,599**	**$56,396**	**$63,014**	0.08	0.10	0.09	0.11	0.09	0.11
<400	135	**$72,680**	**$88,065**	**$98,283**	**$34,643**	**$41,976**	**$46,846**	0.91	1.18	1.01	1.27	1.07	1.33