Highway and Bridge Barrier Rail Report

State of Maine Department of Transportation, November 2016

Introduction

Recent guardrail and bridge barrier rail issues at the national and state level have raised concerns and prompted statewide inspections and investigations into the general condition of barrier and the ability of the barrier to function as intended. In 2015 the Department completed a detailed inventory of the Trinity ET-Plus guardrail end terminals installed along our highways as well as inspections of a random sample. The results show that 14% of these systems are considered nonfunctional[1] while another 24% have some deficiencies when compared to manufacturer's installation details[2]. This prompted a similar 2016 investigation into other end terminal systems to determine if the problems are limited to only one type and manufacturer. The results of this study show 8% to 14% of the end terminals are nonfunctional while 22% to 33% have some deficiencies. Meanwhile the Department has closely inspected bridge rail similar to the Bath Viaduct after a vehicle tumbled over the rail during icy conditions. Finally MASH standards for crash testing barriers are being adopted by AASHTO and the Department needs to develop an implementation plan.

The above prompted the Chief Engineer to sponsor a team to:

- Collect information from other states including policies on barrier retrofits and removals.
- Formulate a plan to gather data in Maine on installation accuracy and current maintenance efforts.
- Evaluate the barrier systems used in Maine and identify risks associated with various systems.
- Prioritize barrier systems used in Maine that should be replaced. This might lead to an annual barrier retrofit or replacement project in the work plan.
- Make recommendations to update the Guardrail and Guardrail Terminal Policy.
- Make recommendations on maintenance of systems.

The team consists of:

- Dale Peabody and Steve Savoy – Transportation Research Division
- Atlee Mousseau – Highway Program
- Jeff Folsom – Bridge Program
- Duane Brunell and Rhonda Fletcher – Employee Development Office
- Brian Burne – Highway Maintenance
- Alan Farrington and Bill Doukas – Bridge Maintenance

[1] Nonfunctional units were determined by a consensus approach where the review team agreed that the condition could very likely hinder end terminal performance.
[2] Some deficiencies were determined by a variance of end terminal condition from the manufacturer's installation details.

This report is organized by the following sections:

Section 2 includes a summary of the report recommendations.

Section 3 includes the methodology and discussion for information gathering and analysis.

Section 4 includes adjustments for existing bridge rail policy, design and maintenance.

Section 5 includes adjustments for existing guardrail policy, design and maintenance.

Section 6 offers recommendations on miscellaneous bridge rail items.

Section 7 discusses MASH implementation plans for highway and bridge barrier.

Finally Section 8 includes appendices.

SECTION 2

Summary of Recommendations

1. Investigate those crash cushions that have been discontinued in other states: does MaineDOT have these assets? If so, should we discontinue and remove from our Qualified Products List? [Adiem, Brakemaster, TRACC]. *Assign to Doug Gayne and Highway and Safety Products Committee*.
2. Revisit the Level of Service written policy for bridge rail, adjusting to the tables presented in Section 4 for clarity in prioritization and damage assessment. Also a slight adjustment in repair scheduling will allow a more realistic and organized effort to keep our bridge rail in adequate condition. *Brian Burne and Bill Doukas to prepare draft changes to Level of Service Policy and present to Superintendent Committee.*
3. Enhance the Bridge Maintenance's inventory for rail. A thorough look at inventory of rail parts over each Region could be developed. This would establish more precisely how much used bridge rail component inventory the Department has identified and if it is adequate. Master agreements or specific manufacturers can be set in place or identified ahead of time. There are many different types of bridge rail, and therefore component permutations will likely make this process more complex than expected. An enhancement of communication between Regions is also a key to quickly locating necessary parts and hardware. *Assign to Bridge Maintenance.*
4. Annual Work Plan Bridge review teams should have as a reference or tool the most recent bridge inventory report of those with rail in condition state #4. See Appendix A. *Assign to Bridge Management.*
5. Consider establishing an in-service bridge rail retrofit program for rail types that may be higher risk systems. For example, aluminum bridge rail non-continuous systems and any bridge rail with a blunt unprotected end (no transition to approach guardrail) pose a higher risk based on the opinions of experienced bridge maintenance staff. *Assign to Bridge Committee.*
6. For local bridges, the Bridge Maintenance office should consider enhancing the "Bad Bridge Letter". Possibilities include a brief paragraph establishing the bridge rail system is part of the liability, perhaps a set of photos clarifying the concern. Although the current letter is adequate, the more direct and specific items addressed in a letter to the municipality, the better. *Assign to Bridge Maintenance.*
7. It is recommended that guardrail inspections be included in a statewide Maintenance Quality Assessment program where a portion of the network is sampled and inspected on an annual basis to provide a gauge of how guardrail condition and repair, among other maintenance items, can be compared across priority corridors and regions of the state. *Assign to Highway Maintenance.*
8. Establish a prioritization and upgrade strategy for the old-style low tension cable rail and the Corten weathered steel W-beam. See photos in Appendix C. *Assign to Highway Maintenance and Highway Committee.*
9. Update the M&O Asset Inventory Manual to better identify guardrail end types. *Recently completed by Highway Maintenance.*

10. Develop guidance and provide training on guardrail system installation and damage assessment to ensure critical issues are given proper priority for replacement and repair level of service. Consider using NCHRP report 656 as a reference for damage assessment. *Assign to Highway Program, Highway Maintenance and Employee Development Office.*
11. Installation accuracy – inspect end treatments installed in 2016 for conformance to manufacturer details, providing baseline data to develop training and performance measures. *Assign to Project Development.*
12. Review the turndown locations identified in MATS as soon as possible to determine our risk if left in place. The department should fund a replacement program in the next 3 year work plan. It is estimated replacement of all turndowns would cost $250,000. *Note: Programmed with Safety Funding in 2019.*
13. Include replacement of all MELT and BCT guardrail ends in capital improvement projects including preservation projects. It is estimated that approximately 300 of these assets per year are within the work area for projects. Some of these are already replaced under the existing Guardrail Policy C8, specifically on Reconstruction and Rehabilitation projects. Our policy should be adjusted accordingly. *Assign to Highway Committee.*
14. Update Guardrail Policy to reflect the shift to MASH to include the Midway Splice Guardrail (also known as the Midwest Guardrail System, or MGS). When MaineDOT establishes that newly installed terminals must be MASH compliant, the Policy will be updated again to reflect this. The updated Policy will address when terminals must be upgraded to MASH compliance and when NCHRP 350 (or lesser) compliant systems may stay in place. *Assign to Highway Program.*
15. For any new guardrail it is recommended to specify the MGS – MASH compliant rail, regardless of highway system or corridor priority. For W-Beam terminals, the department should continue to evaluate MASH compliant systems for inclusion onto the Qualified Products List. Once multiple systems are available, immediately transition to MASH for all new guardrail installations. *Assign to Highway Program.*
16. For Bridge Rail MASH requirements it is understood that the TL-4 may be the critical need. Several options already exist for TL-4 concrete barrier and more may also become tested prior to 2019. For example, TxDOT has single slope concrete barrier rails in 36” and 42” heights successfully crash tested and approved as MASH TL-4 and TL-5 respectively. As other shapes are tested, the department should select one design and update standard details accordingly. *Assign to Bridge Program.*
17. To provide an open rail option, it is our desire to have the NETC style steel bridge rail evaluated under MASH. The department should continue to support and monitor the current NCHRP effort and a proposed new NCHRP study that should provide the necessary evaluation on the NETC style rail. *Assign to Bridge Program.*

SECTION 3

Methodology/Data Collection/Key Points

The approach to this investigation includes a survey of other state DOT's to determine the state of the practice for highway and bridge barrier installations, risks, safety and maintenance. Another important task was to analyze our crash database for any trends or issues with safety of barrier systems. Finally, Identification of our barrier assets with MATS and the Bridge Management/Inspection databases was completed. This information was summarized and discussed during team meetings leading to our conclusions and recommendations.

Current MaineDOT Policy and Guidance

The department has the following policies and guidance documents for barriers:

1. Engineering Instruction C8: Guardrail and Guardrail Terminal Policy dated August 2014. This policy provides instruction for guardrail on capital improvement projects and defines compliance as meeting NCHRP 350 crash testing.
2. Highway Program Design Guidance: Guardrail Upgrade Considerations, dated October 1, 2015. This document provides guidance when to consider guardrail upgrades on restoration and resurfacing projects.
3. Highway Program Design Guidance: Barrier Layout – Length of Need, dated June 1, 2014. This document provides guidance on guardrail length of need.
4. Highway Program Design Guidance: Crash Cushions, dated January 9, 2014. This document provides guidance on use of crash cushions.
5. Level of Service Policy dated 04-15-2011: Roadside Safety Barriers (Activities 137, 139 & 531). This policy provides instruction on safety barrier damage assessment, repairs and schedule.

Survey of other state DOT's

In order to determine best practices in barrier policies, procedures and guidance the team reached out to other State DOTs using a short survey. The team also used this survey as an opportunity to get information on other States MASH implementation plans. The survey questions are part of the appendix to this report.

This survey was sent out on June 16, 2016 to all fifty States and was divided into two sections, guardrail and bridge rail, with some States only responding to one section. The total responses were 26 guardrail and 24 bridge rail coming from a total of 30 States.

Numerous responses to the survey were very informative, giving the team some ideas that could possibly be integrated into MaineDOT policies and procedures. The following summarizes the responses and suggests some actions that could be taken.

Highlights from the survey

1. Does your state have a maintenance program in place to periodically inspect existing guardrail items?

- Missouri's response for periodic inspection of guardrail states, "For some of our major routes, we assign someone to drive the route once a week to log any damage". Details of how damage is assessed and logged were not included.
- Washington State mentioned that they inspect and re-tension median cable barrier annually.
- Nevada's guardrail inspection system "Our maintenance supervisors are assigned a geographic area of responsibility. Part of their responsibility is to inspect guardrail components for proper installation and to repair damage in a timely manner. Periodic safety inspections sometimes include guardrail as a component". They refer to NCHRP Report 656, "Criteria for Restoration of Longitudinal Barriers" when questions come up as to extent of damage requiring repair.
- Arizona does a yearly level-of-service evaluation (based on a random sample of the system) that includes guardrail.
- California DOT: an annual inspection of safety devices on approximately 10% of our Roadways are inspected through our LOS (level of service reviews) noted issues are sent to appropriate staff to schedule & initiate repairs.
- Several states indicated that they have periodic or annual asset inspections that include guardrail items.
- Many states noted periodic or annual inspections of guardrail conducted by Maintenance or Regional staff but there is a lack of specific details on how states conduct and document damage or condition assessment, other than Nevada's reference to NCHRP Report 656.
- Indiana has a policy for attenuators to be inspected annually, guardrail end treatments every 4 years.

2. Has your state identified any guardrail systems that due to crash performance or maintenance issues (durability, expensive repair, etc.) have been discontinued and/or replaced? If so, please provide details.

- California had recently suspended all state approved Slotted Rail Terminal (SRT) systems. CA DOT considers those end treatments to have a manufacturing defect because the assembly instructions do not clearly show the proper orientation of the rails, the instruction drawings are not complete and there are no photos to illustrate correct assembly. This has resulted in some improper installations.
- Michigan suspended use of the Brakemaster 350, a proprietary guardrail terminal manufactured by Energy Absorption Systems (now part of Trinity Highway Products) many years ago due to concerns over a torsion spring detail potential hazard. Note: MATs dB shows 13 Breakmaster systems on HCP 5. Further investigation reveals coding errors so none of these systems are in place in Maine.
- Several states indicated that the ET-Plus end system is no longer used.

- Nevada has removed the TRACC system and the Adiem system completely from their qualified products list due to crash worthiness. Note: MATs dB shows 5 – TRACCS but no Adiem systems.
- Rhode Island eliminated use of Hex foam crash cushion due to its difficulty in maintaining the system, as it uses water. Also had some issues with the SRT-27 at certain locations and use SRT-350 in lieu of it if the contractor wanted that brand.
- Utah no longer allows the QUEST manufactured by Energy Absorption Systems: UDOT has found that when this system is impacted, the system is required to be fully replaced. These systems when impacted are now replaced with a SCI or QuadGuard system. Note: QUEST is not on MaineDOT QPL, or in the MATS dB.
-

3. Does your state have a systemic, risk-based approach to identify guardrail issues and to use this information for data-driven replacement and repair strategies? (do you have a formal process to identify issues and prioritize replacement).

- Most states responded that they have no such program in place.
- Arizona's level-of-service evaluation does this using a representative sample of the guardrail in the system.
- California's level of service evaluation does this.
- Illinois provided recently adopted (December 2015) technical guidance on replacing pre-NCHRP 350 guardrail ends. The guidance is based on analysis of statewide guardrail end crash data over a 5 year period. The guidance provides a method for prioritizing efforts to remove or replace non-350 ends, primarily consisting of blunt ends, turndowns and BCT's. Prioritization considers highway speed, roadway type (NHS), functional classification, AADT and crash history.
- Iowa is developing a process with work by ISU.
- Texas: Field audits are conducted to determine guardrails, and end treatments that are not compliant

4. Does your state have a guardrail level of service repair strategy? (how soon are guardrail systems repaired after damage). If Yes, please provide details.

- Guardrail repair: as soon as practical, 7 days, 10 days, based on level of damage, MassDOT reports 24 to 48 hours, NV: w-beam with > 12" deflection repaired in 24 hours, NY: repairs done < 2 weeks, NJ: emergency situation - immediately, Priority 1 - 30 days, Priority 2 – 60 days, OH: GR – 72 hours to 3 weeks, VT: 2 weeks – 8 weeks depending on priority (similar to MaineDOT)

5. Does your state have a MASH implementation plan for guardrail items?

- Many states are waiting for more MASH replacement options before creating an implementation plan.
- FL attached their implementation plans for highway barrier with dates that follow the AASHTO-FHWA agreement. Will update hardware as projects are let.

- Illinois following AASHTO-FHWA agreement timeline.
- Iowa is already installing Midwest Guardrail System (MGS) barrier rail and recently revised end terminal standards to call out MASH compliant products. As MASH compliant cable barriers, cable barrier terminals, and crash cushions become available, will add them to approved products lists. Investigating the possibility of working with other states to develop MASH compliant bridge rails and concrete barrier rails.
- Missouri had the most aggressive plan to implement MASH stating, "Effective July 1, 2016 we will be installing only MASH end terminals and guardrail on new projects. Also, any damaged end terminals on our major routes will be removed and replaced with MASH end terminals, even if the damage is repairable. The current goal is to upgrade all major routes to MASH within the next 10 years". The Missouri Qualified Products List shows only one MASH approved guardrail end, the SoftStop system.

1. Does your bridge inspection program include specific requirements for bridge rail and transitions (this would be in addition to standard inspections per NBIS)?
    a. MnDOT developed an ADE (#893) for guardrail inspections in accordance with the new NBE inspections. Go to page 166 at this link for details. http://www.dot.state.mn.us/bridge/pdf/insp/bridgeinspectionmanual.pdf We also record the NBI items 36B, 36C and 36D as required per NBIS
    b. Some states noted damaged/deteriorated rail is documented.
    c. Tx DOT - Inspectors are supposed to check the bridge rail, transition, and MBGF and determine if each item is compliant or non-compliant. In addition, they are to take pictures of any damage. The new inspection database system will allow the identified rails, transitions, GF, and end treatments to be entered into the database for query purposes, such as how many are NCHRP 350 compliant, MASH compliant, short due to overlay, etc.
2. Has your state identified any bridge rail systems that due to crash performance or maintenance issues (durability, expensive repair, etc.) have been discontinued and/or replaced? If so, please provide details.
    a. NY DOT mentioned A588 weathered steel rail corrosion issues. This rail has been discontinued and existing weathered steel rail is being replaced.
    b. Florida has phased out non-crash tested bridge rail. On bridge resurfacing projects, rail is upgraded to NCHRP 350.
    c. Iowa provided a detail of aluminum bridge rail replacement with a concrete rail system.
    d. Ohio - For railing not meeting MASH, NCHRP 350 or grandfathered under other NCHRP, the railings shall be replaced during deck replacements, deck edge replacements, superstructure widenings, rigid overlays on NHS routes and rigid overlays on non-NHS routes with design speeds of 40 mph or greater.
    e. Many states acknowledge non-crash tested aluminum bridge rail and have discontinued usage.

   f. Washington State has a lot of pre-1980's bridge railing systems. They have identified all of the older systems that did not meet the 10 kip load and have either replaced them or modified them with a thrie-beam guardrail retrofit. For bridge widening or replacement the bridge traffic barriers are upgraded to a TL-4 system

3. Does your state have a systemic, risk-based approach to identify bridge rail issues and to use this information for data-driven replacement and repair strategies? (do you have a more formal process to identify issues and prioritize replacement). If Yes, please provide a description.
   a. Texas has adopted a bridge rail replacement program funded at $5 million annually. This program replaces non-compliant rail on bridges that are generally in good condition. Guidance and policy documents are available.
   b. MassDOT does try to retrofit non-crash tested railings and barriers on interstates as part of an interstate maintenance program, but outside of interstates, do not retrofit or replace railings unless there's a deck replacement or greater project.
   c. Oregon DOT uses a rail priority program based on the total points that are determined for each bridge. The starting point is NBI 36A, the Bridge Railing Traffic Safety Feature. If the bridge rail meets standards, there are "0" points and no further consideration in the Rail Prioritization Program. The other factors considered include curb, rail design, functional class, condition, etc. These are simply multiplied together to determine the overall multiplier for the bridge.
   d. Washington State Department of Transportation's (WSDOT) bridge rail retrofit program. Prior to 1984, other than a program to upgrade low-base aluminum rails, the department's informal policy on replacing substandard bridge rails was to incorporate a replacement in a highway construction project to obtain a desired roadway width mandated by accident history. Otherwise, bridge rails were exempted from a project even if the approach rails were upgraded. As a result of this retrofit policy, substandard bridge rails are being upgraded systematically, on an individual project basis, as part of WSDOT's resurfacing, restoration, and rehabilitation (3R) program. The retrofit program was developed to provide a uniform policy for upgrading substandard bridge rails.
4. Does your state have a bridge rail level of service repair strategy? (how soon are rail systems repaired after damage). If Yes, please provide details.
   a. Common replies were "none", 7 days and as soon as practical for repair of damaged rail.
   b. NJ DOT repairs based on emergency situation (immediate repairs), Priority 1 (30 days) and Priority 2 (60 days)
5. Does your state have a MASH implementation plan for bridge rail? If Yes, please provide a copy.
   a. Most responded that no MASH plan is developed yet. Many indicated awaiting results of NCHRP sponsored and other pooled fund projects. Some states indicated that the plan is under development.

Safety Data

The two main focuses for safety data evaluation was corridor priority, to prioritize what roadways would need to be a primary focus, and injury data, to evaluate the exposures of guardrail and bridge rail. These injuries were also compared to other deadly fixed objects like trees, ditches, and utility poles.

The safety data that was utilized by the team consisted of crash reports for bridge rail, guardrail face, and guardrail ends. The crash report database was queried using two different methods. First was by using "sequence of events". Each crash report is divided into anywhere between one and four sequence of events that describe what happened during the crash. For example, Event 1: Went of roadway left. Event 2: Guardrail End. The crash ends here so event 3 and 4 are left blank. Unfortunately, a problem arises with this method when a serious crash occurs in the roadway, and the vehicle comes to a rest at the guardrail face. Though the guardrail face is part of the crash it wasn't a major factor, or the cause of a fatal or incapacitating injury. This method tends to skew the results.

The second method for reporting uses the "most harmful event" from the crash report. In this method the result only shows what caused the most damage or injury. This removes most fatal crashes that were caused by things other than guardrail, but still isn't a perfect methodology. In the case of guardrail ends several serious injuries could occur after running into the end terminal and rolling over. The "most harmful event" may be listed as a roll-over, but the roll-over potentially was caused by hitting the guardrail end. It is extremely important to understand the limitations of using the crash data with either above methods. Without a detailed investigation of each crash it is near to impossible to determine the exact cause of injuries or fatalities or how well the rail performed. However general trends in the data can be used to develop conclusions with a good level of confidence, and when considering the two above data approaches concentrating the analysis on "Most Harmful Event" provides the most effective data and outcome relationship.

The following table shows guardrail face and end crashes for the period 2012 – 2016. The data does not include the full year for 2016.

Guardrail Face Crashes with "Most Harmful Event" 2012 -2016			Guardrail End Crashes with "Most Harmful Event" 2012 - 2016		
	Count	Percentage		Count	Percentage
Fatalities	7[3]	< 1%	Fatalities	2	<1%
Incapacitating Injury	44[4]	1.7%	Incapacitating Injury	11	2.5%
Evident Injury	241	8.4%	Evident Injury	51	11.7%
Possible Injury	382	13.4%	Possible Injury	88	20.1%
No Injury	2182	76.5%	No Injury	284	65%
Total	2854		Total	437	

Table 1 – Guardrail Face Crashes and End Crashes with MHE

[3] Motorcycle crashes accounted for 4 fatalities
[4] Motorcycle crashes accounted for 13 incapacitating injuries

In Maine during this review period a total of about 148,000 reportable crashes occurred. A total of 2854 crashes occurred where the "most harmful event" is the guardrail face hit. Of these 77% reported no injuries while less than 1% were fatalities. For guardrail ends a total of 437 crashes are reported as "most harmful event". Sixty-five percent (65%) had no injuries and less than 1% resulted in a fatality.

In a fuller context, the next table shows crashes with fatalities and incapacitating injuries, categorized by all types of "Fixed Objects Struck" (FOS). These objects are often hazards that a guardrail or barrier installation can provide protection. Striking fixed objects are often the ultimate source of serious injury or death. Maine's crash data indicates that striking a fixed object is the most harmful event 5500 times a year. Crash data can be evaluated on the basis of number of crashes and resulting injuries, or on a severity basis by calculating injury outcomes on a rate per 1000 crashes of that type.

- For ditches there are (15/4331)x1000 or 3.5 fatalities for every 1000 crashes and 26 incapacitating injuries per 1000 ditch crashes.
- For guardrail face there are (7/2854)x1000 or 2.5 fatalities for every 1000 crashes and 18 incapacitating injuries per 1000 guardrail face crashes.
- The guardrail ends have higher rates than guardrail face (4.6 fatalities per 1000 crashes and 30 incapacitating injuries per 1000).

For the guardrail ends, it may not be reasonable to draw a comparison to fixed objects such as ditches and guardrail faces. A more relatable comparison would be a point object such as utility poles (5.6 fatalities per 1000 crashes and 32.5 injuries per year). The purpose of the guardrail ends is protection from an exposed guardrail, mostly W-beam, which would cause much more serious harm to errant vehicles and occupants. There are obviously many variables such as vehicle speeds, angle of crash, etc. that cannot be taken into account. The guardrail and guardrail ends are intended to provide a safer environment when compared to other roadside features that are commonly hit by vehicles, but won't eliminate all fatalities and injuries.

Fixed Object Struck (FOS), Most Harmful Event 2012 – 2016 (YTD – Oct.)	**Crashes**	**% of Total FOS Crashes**	**Fatalities**	**% of Total FOS Crashes**	**Incapacitating Injuries**	**% of Total FOS Inc. Inj.**
Tree (standing)	6602	25%	124	60%	464	46.6%
Ditch	4331	16%	15	7.2%	113	11.3%
Utility Pole/Light Support	5311	20%	30	14.5%	172	17.3%
Embankment	2323	8.7%	10	4.8%	71	7.1%
Mailbox	559	2.1%	0	0.00%	5	0.5%
Traffic Sign Support	491	1.8%	2	0.97%	1	0.2%
Culvert	333	1.3%	2	0.97%	23	2.3%
Guardrail Face	2854	10.7%	7	3.4%	52	5.2%
Guardrail End	437	1.6%	2	1.0%	13	1.3%
Bridge Rail	319	1.2%	0	0.00%	11	1.1%
Cable Barrier	167	0.6%	0	0.00%	1	0.1%
Impact Attenuator/Crash Cushion	230	0.9%	1	0.4%	10	1.0%
All Other Fixed Object	2698	10.1%	13	6.3%	60	6.0%
Totals	26655		206		996	

Table 2 – Fixed Object Struck, MHE, Fatalities and Incapacitating Injuries

Fixed Object Struck with "Most Harmful Event" Average Annual Crash #		**Five Year Rate/1000 crashes**	
		Fatalities	**Incapacitating Injuries**
Tree	1400	18.8	70
Utility Pole/Light Support	1100	5.6	32
Guardrail Face	600	2.5	18
Guardrail End	92	4.6	30
Bridge Rail	67	0	34
Ditch	912	0	26
Embankment	489	4.3	31
All Other	840	-----	-----

Table 3 - Fixed Object Struck with Most Harmful Event Average Annual Crash #'s and Five Year Rates

NOTE: Careful examination of the crash reports indicates a likely error in coding for Report 2013-20645. The correct coding for MHE should be Guardrail Face. Thus Guardrail Face fatalities = 7, fatality rate = 2.5, Guardrail End fatalities = 2, fatality rate = 4.6

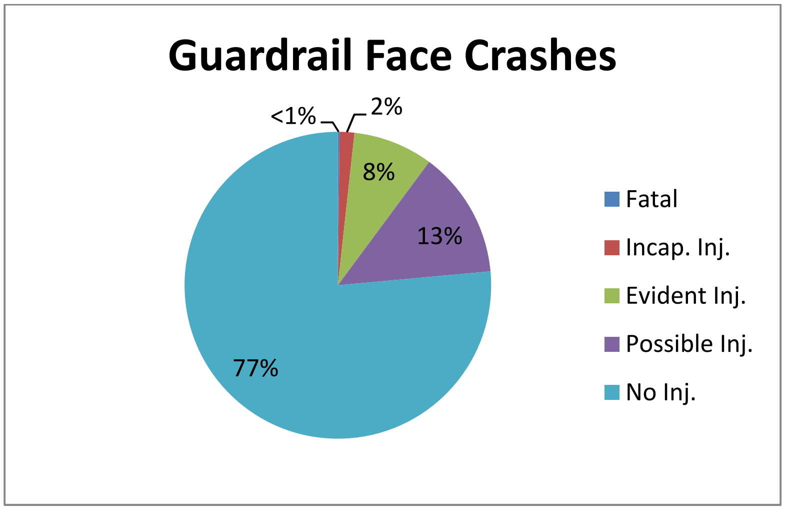


Figure 1 - Crashes when Guardrail Face the "Most Harmful Event"

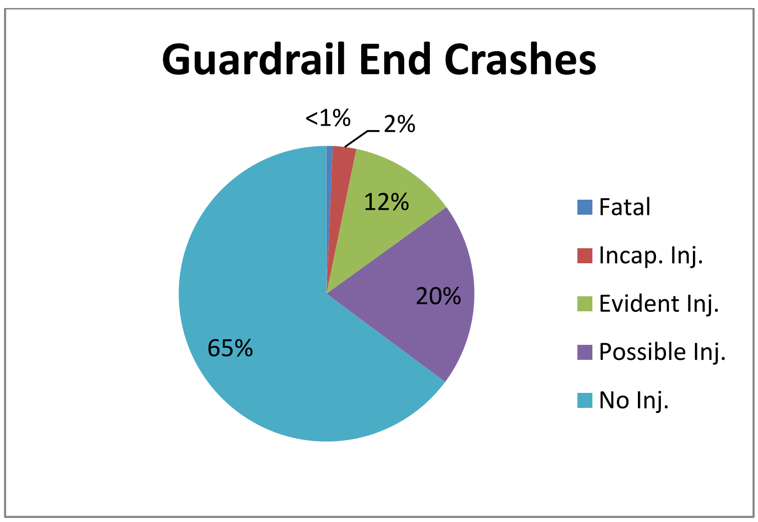


Figure 2 - Crashes when Guardrail End the "Most Harmful Event"

Bridge Rail Crashes with "Most Harmful Event" 2012-2016		
Crash Injury Level	**Count**	**Percentage**
Fatalities	0	0.00%
Incapacitating Injury	10	3.13%
Evident Injury	30	9.4%
Possible Injury	48	15%
No Injury	231	72.4%
Total	**319**	**100.00%**

Table 4 – Bridge Rail Crashes with MHE

For bridge rail with "Most Harmful Event" there were 318 crashes with zero fatalities and 10 incapacitating injuries in the 2012 – 2016 time period, about 67 crashes per year. The incapacitating injury rate is higher than guardrail and guardrail ends at 34 per 1000 crashes. This would be expected since bridge rail is not a flexible, energy absorbing system but a more rigid system to protect vehicles from going off the bridge.

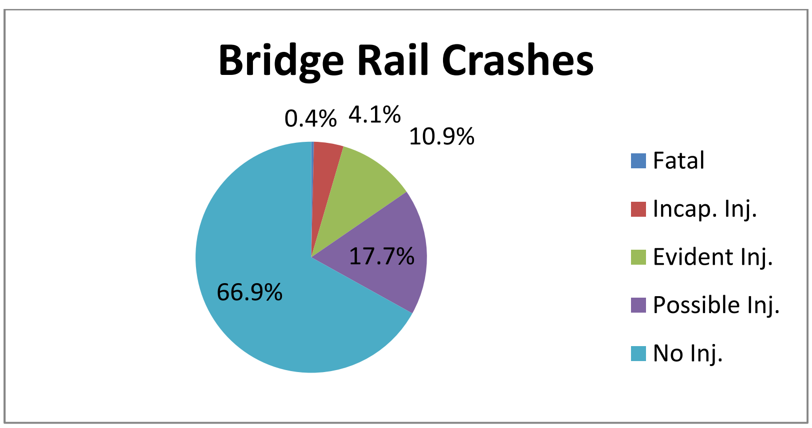
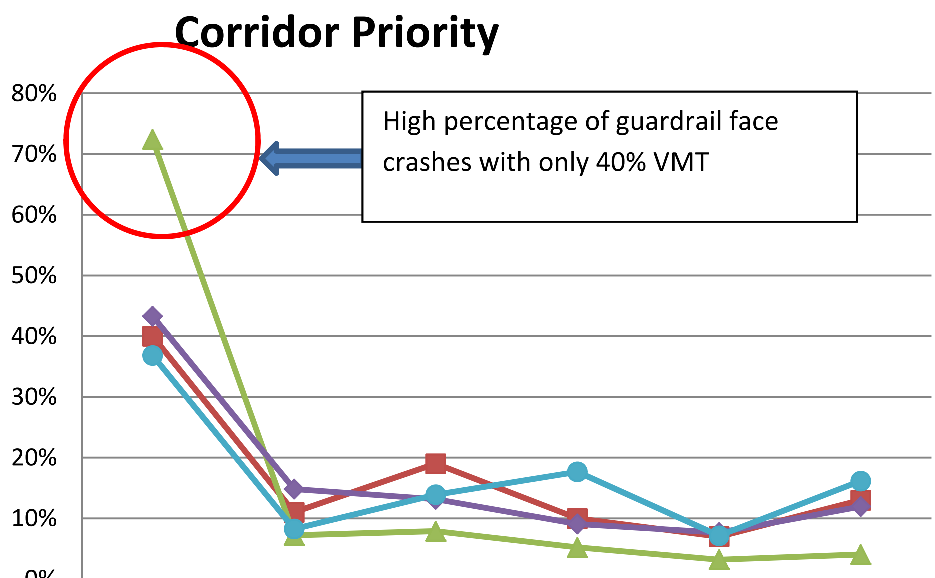


Figure 3 - Crashes when Bridge Rail the "Most Harmful Event"

Crash reports indicating the Most Harmful Event as guardrail face, guardrail end and bridge rail were reviewed for any fatal or incapacitating injury. These reports include a narrative and crash diagrams which can give a much clearer image of what happened during the crash. Unfortunately, review of these crash reports do not give sufficient details to determine for certain if the rail system did perform as intended. Only a detailed forensic investigation for each crash could provide that needed level of detail.

The crash types were categorized by highway corridor priority (HCP) for review and analysis. All things being equal, it would be expected that the percentage of crashes would be similar to the percentage of vehicle miles traveled. That is, if 11% of VMT travels on HCP 2 one would expect roughly 11% of the crashes to occur on HCP 2.



	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5	Priority 6
Total Amount of Traffic	40%	11%	19%	10%	7%	13%
Guardrail Face Crashes	72%	7%	8%	5%	3%	4%
Guardrail End Crashes	43%	15%	13%	9%	8%	12%
Bridge Rail Crashes	37%	8%	14%	18%	7%	16%

Figure 4 – Crashes by HCP

Conclusions from safety data:

- All but one of the bridge rail crash reports reviewed indicated that vehicles were stopped from going off the bridge into the hazard below (Bath Viaduct crash 2016). We do know there certainly are exceptions from case histories and that each incident should be carefully investigated before implementing any changes.
- Number of crashes generally correlate with the HCP VMT. One would expect most of the crashes to occur on HCP 1 since these roadways carry 40% of the total VMT.
- For guardrail face crashes there are 72% of the crashes on HCP 1. Thus crashes are over represented in this case. From exposure rate one would expect around 40% of the crashes. It may be that the total mileage of guardrail is a higher percentage on HCP 1? It is likely not easily explained using the available data but could be due to vehicle speeds, congestion, volume, etc.

End Terminal Inspections

The end terminal inspections were conducted as a separate project, but information gathered during that project was shared with our team in order to create recommendations for guardrail ends.

A random sample of the ET-Plus, Fleat, and SRT systems were inspected in 2015 and 2016 after safety issues were raised about the installation and the use of the ET-Plus. The following table summarizes the results.

	FLEAT WP		SRT 27 SP		SRT 350		ET PLUS	
Characteristics	*Number*	*Percentage*	*Number*	*Percentage*	*Number*	*Percentage*	*Number*	*Percentage*
Functional or Fully Functional	*60*	*59%*	*38*	97%	*46*	71%	*53*	62%
Some Deficiencies	*34*	*33%*	*1*	3%	*14*	22%	*21*	24%
Non Functional	*8*	*8%*	*0*	0%	*5*	8%	*12*	14%

Table 5 – Guardrail End Inspection Summary

During the inspections a total of 210 terminal ends were inspected, and categorized into three condition states.

- Functional - Functions as designed.
- Some deficiencies - Functions but not as designed and/or has some minor deficiencies.
- Non-Functional - Doesn't function and/or has some major deficiencies.

The results have led to recommendations for improved and more widespread training on installation procedures and fully support recent efforts within M&O to have more focus on guardrail asset maintenance and repair.

MATs Queries

A MATS query was completed to report the number and types of guardrail ends by Highway Corridor Priority currently in our inventory. See Table below.

The database reports 37 turndowns still exist with 28 of these being on HCP 1. These systems were discontinued in the 90's due to safety performance issues. Each of these locations should be reviewed to determine if a turndown actually exists, does it impose a safety concern and how the system should be replaced.

Figure 3 - Typical Turndown Installation

Other end treatment systems that should be investigated are the BCT and MELT systems. The BCT is a pre-NCHRP 350 crash tested device that were first introduced in the 70's and widely used for about 20 years. The MELT system was introduced as an improvement to the BCT to gain more tolerable vehicle deceleration rates. The MELT 350 TL-2 designation indicates it was tested to 350 crash criteria at 43.5 mph impact speed. As MaineDOT moves to the next level of crash testing (MASH) it would seem logical to begin to replace the pre-350 systems in a more accelerated manner. First, the overall condition of these older systems might be a concern and secondly the crash test worthiness is dated. Based on the MATS report there are approximately 1850 MELT units and 4000 BCT units in place for a total of 5850 units. A review of the current three year work plan shows 900 of these units are on or near project locations. At an estimated replacement cost of $3000 and replacing 300 per year the annual cost is $900,000. The time to replace all 5850 units is approximately 20 years, assuming 300 per year and replacements are part of the scope of work for all projects including pavement preservation.

In the 90's the energy absorbing terminals were developed. These ends provide optimized vehicle deceleration and are NCHRP 350 tested. These ends along with the Slotted Rail Terminal (SRT) are the most commonly used 350 ends today.

MATS Query for Guardrail Ends by HCP							
Highway Corridor Priority	1	2	3	4	5	6	Total
W-Beam Terminals							
Energy Absorbing Terminals (350)							
Energy Absorbing Terminal - unknown	106	64	231	123	23	1	548
ET Plus (4 Inch Guide)	60	110	75	87	23	4	359
ET Plus (5 Inch Guide)	4		4				8
ET2000	24	30	21	34	26		135
FLEAT350	821	371	145	58	25		1420
FLEAT-MT	11						11
SKT 350	27	5	4	18	2	1	57
X-LITE		2	1		2		5
Other 350							
SRT350	1116	386	277	178	81	3	2041
Continuous	928	539	542	277	187	14	2487
Buried in Backslope (350)	14	28	9	2			53
Radius	607	814	1474	2253	1949	92	7189
MELT 350 (Test Level 2)	491	415	517	286	106	10	1825
Other Pre-350							
Low Volume End	537	32	58	192	151	2	972
Terminal End - Boxing glove	897	38	177	326	178	8	1624
Breakaway Cable Terminal (BCT)	758	895	1503	648	187	14	4005

Turn-down	28	8			1		37
Crash Cushions/Attenuators							
BreakMaster (350)					13		13
CAT (350)	69					1	70
QUADGUARD (350)	3		1	1			5
REACT 350	8		2				10
TRACC (350)	4			1			5
Grand Total	6513	3737	5041	4484	2954	150	22879

Table 6 – Guardrail End MATs report

In order to further investigate the high percentage of guardrail face hits on HCP 1 roadways, a MATS query for guardrail total length was completed and then mapped to determine percentage of guardrail length in each HCP. The data shows that HCP 1 has 400 miles of guardrail on 1751 centerline miles. This equates to roughly 23% of the total centerline miles. By comparison, HCP 2 is 17% and HCP 3 is 13% of guardrail mileage to centerline mileage. There does appear to be an increased exposure level on the HCP 1's. A much more detailed analysis may help better explain the higher percentage of guardrail face hits.

The Bridge Management database was queried for any bridges with condition state #4 for bridge rail. This indicates a portion of the rail element warrants further review to determine the effect on strength or serviceability. A total of 86 bridges were reported with at least some percentage of the rail in condition state 4. Around 56% of these bridges are municipal owned and maintained. There is a mix of rail material type including timber, steel and concrete rail. Highway Corridor Priority, AADT and other conditions can be included in this report. For example, Bridge #6311 in Bowdoinham is on HCP 1 with 10960 AADT. The bridge rail is metal (Aluminum) and has 3% of length in condition state 4. Further investigation revealed that one post has missing bolts into the concrete curb. This is important information that could be used by bridge review teams and others.

In a related effort to this report, in order to improve the bridge rail inventory, all bridges were reviewed to document the rail material type and other details such as foundation, number of rails, rail shape, etc. This data was compiled in an Excel spreadsheet and exists within the Bridge Maintenance office. The spreadsheet can be used as a supplement to the NBIS bridge data.

SECTION 4

Existing Bridge Rail Adjustments in Policy, Design and Maintenance

MaineDOT's bridge rail systems have performed well with minor exceptions that were caused by extraordinary events. Since the Team was unable to develop a correlation between accidents and particular bridge rail exposure, discussions and recommendations for improvements are based on an understanding of exposure level, experience and judgement.

In general, Maintenance & Operations improves bridge rail systems. Eliminating all risk situations due to bridge rail conditions would inhibit efforts to improve structural or capacity items because of available resources. However, several topics deserve consideration: 1.) Revisiting the Level of Service Policy of Roadside Safety Barrier and 2.) Retrofit Considerations. These 2 topics will require engineering judgement considering highway approaches, geometry, speed and AADT, with regard to bridge rail, before practical decisions are made. This is paramount in prioritizing Department Bridge Rail strategy.

REVISITING LEVEL OF SERVICE POLICY

The current Level of Service Policy of Roadside Safety Barriers within the Maintenance & Operations Activities published in February 2015 was reviewed by committee members. This policy publication recognizes Bridge Rail as well as several highway components and establishes a repair schedule for critical and non-critical damage. A post-winter window of 45 days is specified for Priority 1 corridors to repair all Roadside Safety Barrier damage ending June 15th.

Although adequate, elaborating and adjusting this written policy would assist in clarifying direction of bridge rail damage issues. A summary of W-beam barrier descriptions of repair thresholds is included in NCHRP Report 656 and could be adopted for bridge rail repair. For clarity a matrix aimed at labeling damage priority levels is listed below.

Priority Level	Description
High	A second impact results in unacceptable safety performance including bridge rail penetration and/or vehicle rollover.
Medium	A second impact results in degraded (but not unacceptable) safety performance.
Low	A second impact results in no discernible difference in performance from an undamaged bridge rail

Table 7 - Priority Level Scheme

Currently the Level of Service Policy would indicate "critical damaged" bridge rail is to be repaired within 1 week on Priority Corridors 1 thru 5. Several issues could cause difficulty in carrying out this directive such as:

1. Determine precisely what is considered "Critical Damage".

2. Obtaining repair parts. Often existing older bridge rail components are difficult to procure. There is either a long lead time for hardware or crews search stockpiles of existing used parts. For some situations it may not be possible to accomplish repairs within One Week.

Bridge Rail is made up of Rails, Posts and some sort of Concrete Base. However, there are exceptions. Clarifying the priority level of bridge rail damage will assist Crew Supervisors and Bridge TOMs in carrying out appropriate action.

This is accomplished by utilizing the Priority Level Table above, as a general consideration, and the Table 2 below for more specific evaluation. Rather than 2 categories of Critical and Non-Critical, there would be 3 categories: High, Medium and Low.

Description	**Priority Level**
Missing or Dislodged Rail	High
Severe Tear in Rail: Tear is vertical and greater than ¼ rail height dimension	High
No Attachment to Transition Piece	High
Severe Dent in Rail: Dent affects rail circumference by more than ⅓.	Medium
Single Splice Piece (between rails) Missing	Medium
Non-Severe Tear or Dent	Low
Attachment of Rail to Post (Single location)	Low
Minor Dents and Scratches in Rail	Low

Table 8 - Rail and Rail Splice Damage

Post evaluation is somewhat more difficult as it is a function of continuous frequency, percentage of anchor bolt fasteners compromised and condition of post. A Post Damage Matrix could be utilized to assist in determination of High, Medium or Low priority level of repair.

Matrix 1 - Post Damage

Hardware and condition on each individual post

	Missing zero fasteners. Missing one fastener. Missing 25% Fasteners. Tear, broken weld, puncture in less than 25% of post cross-section.	Missing more than 25% fasteners.Half the fasteners missing. 75% fasteners missing. Tear, broken weld, puncture in more than 25% of post cross-section but less than 50%.	More than 75% fasteners missing. All the fasteners missing. Tear, broken weld, puncture in more than 50% of post cross-section.
ONE POST IN A ROW	LOW	LOW	MEDIUM
TWO POSTS IN A ROW	LOW	MEDIUM	HIGH
THREE POSTS IN A ROW	MEDIUM	HIGH	HIGH

Judgment can be used by an engineer or Bridge TOM to make final determination of priority level.

Concrete Bases, supporting a Bridge Rail System can also be challenging in evaluation. There are levels of concrete deterioration which need judgement to categorize. The area of concern is usually the portion below a post baseplate; however, in some cases, the full length of the system (all concrete “city” rail). A High priority repair may have exposed rebar, baseball size, and larger chunks of concrete missing or large cracks extending from the anchor bolts to edge of concrete base.

Figure 6 - Typically a concrete base repair would be focused beneath or partially beneath a rail post.

If any of the 3 general portions of the system - Rails, Posts, or Concrete Bases are determined as High Repair Priority, the entire repair would be considered High and scheduled accordingly. Issues of highway and bridge geometry, speed as well as AADT are additional considerations in finalizing a Repair Priority Level. The following is a suggested Repair Schedule for Bridge Rail:

Repair Schedule	Corridor Priority 1	Corridor Priority 2	Corridor Priority 3-6
High Repair Priority*	2 Weeks	2 Weeks	2 Weeks
Medium Repair Priority	6 Weeks	6 Weeks	6 Weeks
Low Repair Priority	3 Months	3 Months	6 Months

Table 9 - Proposed Bridge Rail Repair Schedule

* Window of High Repair Priority 1 remains between April 30th and June 15th if snow banks, etc. prevent operations.

Revisiting the Level of Service written policy, adjusting to these above tables/matrix for clarity and a slight adjustment in repair scheduling will allow a more realistic and organized effort to keep our bridge rail in adequate condition.

Current policy requires a 1 week repair schedule for "Critical Damage on HCP 1 – 5. It may make sense to extend bridge rail repair that is high priority or considered critical to 2 weeks. The use of temporary concrete barrier is a viable option but adds its own set of risk to public by narrowing the roadway and challenges snow removal. An additional week in an acceptable but still High Priority condition may allow successful location of parts. (No different than a W-Beam Crash End, etc.) Currently, the Level of Service Policy indicates that accumulated damage is exempt from the current 1 week schedule because of snow banks/seasonal issues. An enhanced inventory program may reduce public exposure in these cases as well.

A 6 week repair schedule for Medium Priority Repairs on Bridge Rail Systems allows a normal lead time of 5 weeks to procure parts.

This report can only initialize the effort in enhancing Bridge Maintenance's inventory position. A thorough look at inventory of rail parts over each Region could be developed. This would establish more precisely how much used bridge rail component inventory the Department has identified and if it is adequate. Master agreements or specific manufacturers can be set in place or identified ahead of time. There are many different types of bridge rail, and therefore component permutations will likely make this process more complex than expected. An enhancement of communication between Regions is also a key to quickly locating necessary parts and hardware.

It is recommended that a presentation be given at the Bridge TOM meetings to develop a uniform level for Critical or High Priority damage that must be repaired within the scope of the Level of Service Policy. Further details may be worked out.

A presentation should also be given at a Bridge Inspector Meeting to instruct collection of appropriate level of bridge rail conditions. A bridge maintenance team could put together a set of forms and guidance documents that more easily directs the bridge inspector's focus and ensures relevant data collection. A process could be considered to move this information to Bridge TOM's & Crew Supervisors in an orderly fashion.

RETROFIT CONSIDERATIONS

There is insufficient evidence to recommend completely retrofitting any single type of design, but the Bridge Committee has noted a few that may not perform as well as expected in the event of an incident.

As there was no successful correlation between accidents and bridge rail type, the judgement of risk and exposure becomes the best mechanism for a strategy. In order to enhance this effort, bridge maintenance staff members were interviewed.

The decision to retrofit or replace a bridge rail system resides with the 2 teams that visit bridge projects annually: (1) Capital, Planning and Maintenance Representative Engineers and (2) Region Bridge TOM's, Bridge Maintenance and Regional Engineers. These teams input are the "triggers" to change out a bridge rail system as they have good knowledge of funding and can best compare situations to establish project priorities. Team (1) focuses on Corridors 1, 2 & 3 while team (2) focuses on Corridors 4, 5 & 6. These site investigations take place simultaneously and there is some cross-over discussion between teams to gather input & advice. These teams, close to the time of the site visits, should determine if bridge rail shall be rehabilitated or replaced. Bridge TOM's, with input/advice from Crew Supervisors, should inventory their Region's bridge rail and identify their perspective of needs ahead of these visits.

Deck Replacement shall continue to include an acceptable rail that meets current standards. Combining Wearing Surface jobs with Bridge Rail Rehabilitation or Replacement does not have equivalent efficiencies. Work cannot be performed simultaneously and therefore would simply extend the theoretical necessary work time. However, there is some economy of scale advantage by combining contract administration efforts and traffic control planning. If the bridge is not anticipated to undergo work within the current or foreseeable work plan, the teams, or a part of a team, mentioned above may certainly consider a system be engineered to improve or replace the rail.

Bridge Approach Rail Maintenance and retrofit is currently addressed in an internal publication, MaineDOT Bridge Maintenance Standards, <u>BR 603 Bridge Approach Rail Maintenance</u>.
This Standard will be refreshed in the near future as the last revision was internally published on 8/14/01. Either of the 2 teams mentioned above may elect for the "4 corners" of approach rail to be rehabilitated in accordance with Appendix B. If the bridge is state owned and located on a town way, the municipality will be notified in writing of the deficiencies and given an opportunity of provide satisfactory approach rail improvements immediately following state work or possibly within the Department's work zone. (See Appendix B)

<u>The following may serve as an initial guide to the Department's In-Place Bridge Rail Strategy:</u>

Surveying a sample of the bridge maintenance community revealed some common ideas with merit. There are numerous types and permutations of in-place bridge rail systems. Aluminum bridge rail types vary by age. The older systems should be targeted first for replacement or retrofitted. There are concrete bridge rails systems that could compete as initial targets for improvement. Below is an explanation of logic that should drive a priority list:

- Aluminum Rail Components that are non-continuous (i.e. begin and end at each post). These round tubular parts fit inside a socket with little perimeter support. They are predicted to come entirely loose if a post is deflected enough. This rail is representative of the oldest aluminum bridge rail systems.
  - Higher probability of rails becoming dislodged.
  - Anchor Bolts appear to sometimes be made of Aluminum (see Figure 7).
  - Very difficult to maintain. Few suppliers of aluminum parts results in procurement issues.
  - The lower yield strength than steel results in higher probability of failure in shear and bending.
  - No Crash-testing in that era.
  - Height issues.

  Retro/Replacement Priority: High

- Aluminum Rail Components that are continuous (i.e. fit through post or posts configuration and join via splice to another rail). Similar to 1 above however:
  - Difficult to maintain. A "Toggle Bolt" secures the rails to the posts which has proven to be a maintenance challenge. Often this hardware disappears. Dissimilar metals is a suspect.
  - A splice between rails – pipe within a tubular rail has improved the system.

  Retro/Replacement Priority: Medium

- Aluminum Elliptical Rail (same shape as name) is a system the Bridge Maintenance Community has relatively more confidence.
  - Appears the bridge maintenance community has been able to collect a good supply of "used" components of this system.

  Retro/Replacement Priority: Low

- Concrete 2-Bar Rail is identified in some cases to contain risk exposure. These are concrete posts with pockets in them to accept concrete rail components.
  - Clearly non-continuous,
  - More easily deteriorates with elements and time.
  - Replacing & repairing components is challenging. When the lower rail is mounted to the curb, the labor effort is even more extensive.

  Retro/Replacement Priority: Medium

- Any bridge rail with a blunt unprotected end.
  - In early times, there were no designed "transition" sections between bridge rail and approach guardrail.
  - There are cases were even a connection between bridge rail and approach rail may not exist.

  Retro/Replacement Priority: High

- Other. There are many other bridge rails that by a brief review would place them in a High Retro/Replacement Category. Unlike guardrail, bridge rail types vary widely in configuration. A lot of them are steel that generally appear light in structure. Undoubtedly these would creep quickly into any In-Place Bridge Rail Strategy.

During the summer of 2016 a spreadsheet was developed from the bridge management database that listed bridge rail with a sizeable percentage outside of State 1 Condition (good condition) and identifying % of length in State 4 Condition (poor condition). The location's Environment and Type of Rail are listed as well. This spreadsheet, updated on an annual basis, could serve as a useful tool for the 2 teams that have the task of identifying bridge rail work for the work plan (See Appendix A).

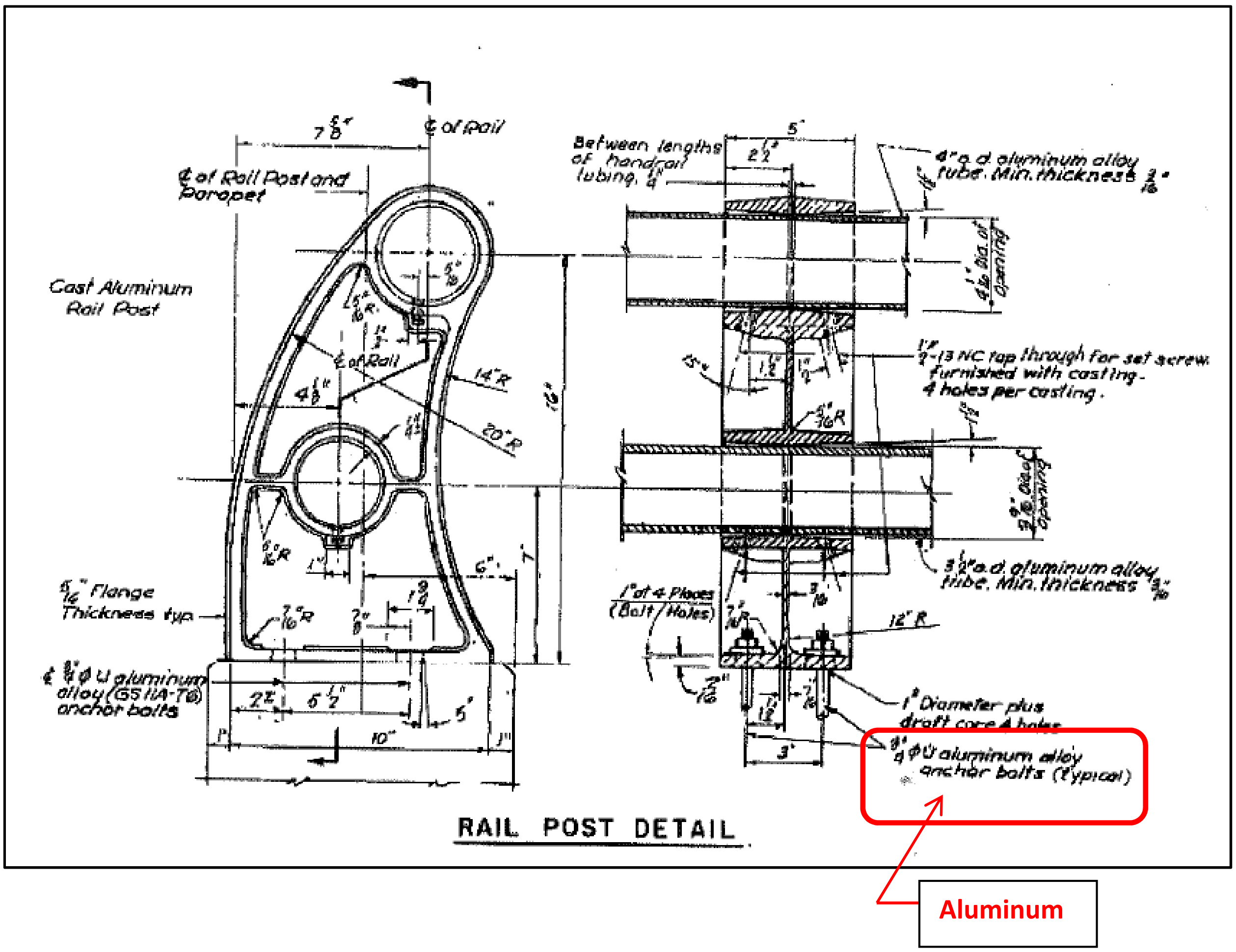


Figure 7 – Aluminum Rail Post For Non-Continuous Rail

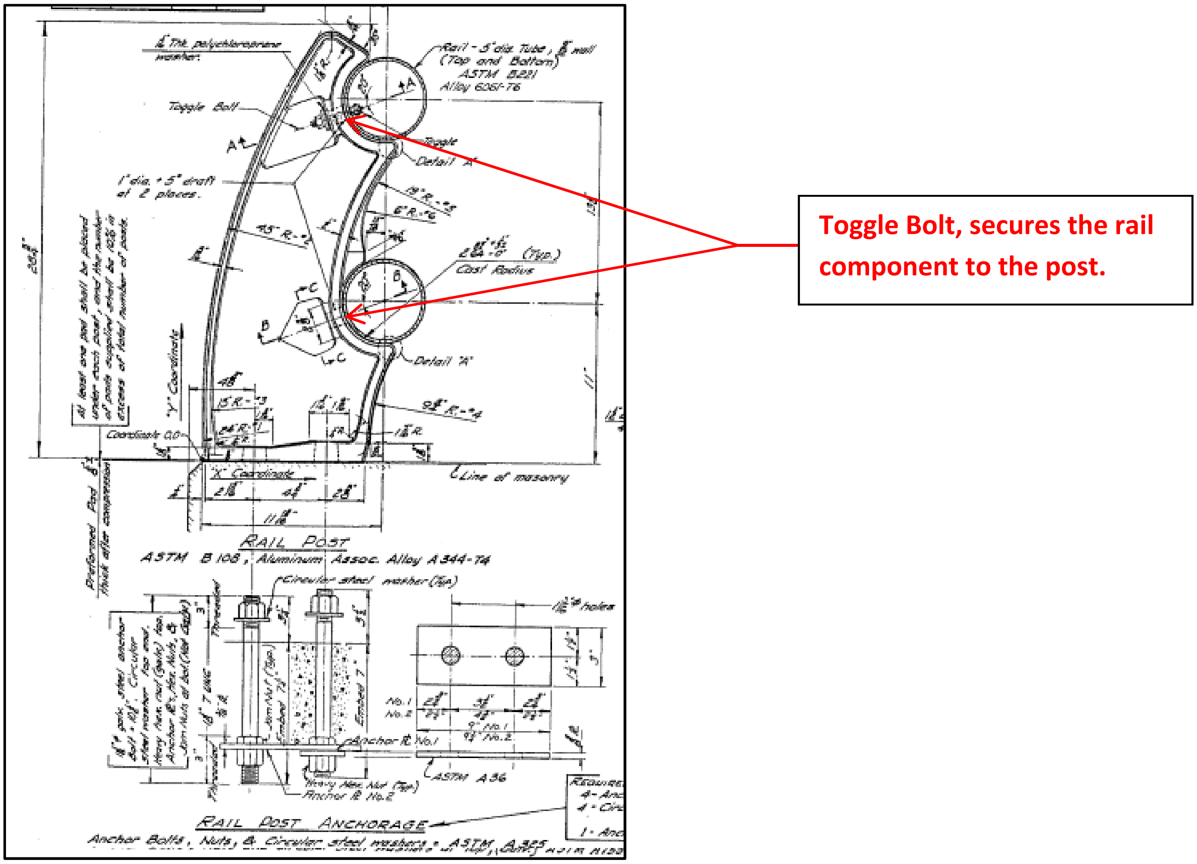


Figure 8 – Aluminum Rail Post For Continuous Rail

An effective retrofit and/or replacement priority list based on location, condition, future/upcoming work plans and funding along with the above Retrofit/Replacement Categories of High, Medium and Low could be developed. A successful policy additionally must take into consideration highway approach, geometry, speed and AADT. The Department would be able to target the older aluminum and concrete rail as priorities in an overall strategy. This effort will best address Department risk exposure.

Retrofit/Replacement Alternatives

Once again, sharing practicalities with field, managerial and technical bridge maintenance personnel resulted in reasonable retrofit alternatives. Be aware that some of these are improvements and not necessarily crash-tested systems and the Department may be accepting a certain level of responsibility if implemented. Below are the most mentioned alternatives to improve or mitigate a bridge rail system that appear logical:

- Remove and replace all bridge rail components from the top of the curb up.
    - This would require the use of a chemically bonded anchor bolt embedded in existing concrete – to assure acceptable post fastening.
    - The Department would be accepting the concrete internal configuration & condition.

- A testing plan for the new anchor bolt embedment strength could be arranged.

➢ Remove and replace all bridge rail components into the curb or sidewalk and below.
  - This would involve the concrete removal and replacement at least to below the rail post anchor bolt assembly.
  - It appears this alternative would require a crash-tested system.

➢ Utilize Stub Posts mounted in front of in-place rail system.
  - This is favored by field personnel as they are easy to have fabricated and can be used with guardrail or thrie beam.

➢ Utilize Thrie Beam mounted in front of in-place rail system.
  - This is favored by field personnel as these components may be mounted to existing posts, concrete structures or Stub Posts.

➢ Mitigate blunt ends of bridge rail configuration.
  - Requires a case by case analysis as these situations are unique.

Developing a plan to connect bridge rails will be challenging as they are unique situations.

Selecting the correct retrofit and/or replacement alternative may be challenging. Identifying the best retrofit for a particular situation while mindful of an overall in-place bridge rail strategy will undoubtedly be a “work in progress”. Maintenance forces have implemented all of the alternatives highlighted for some time now. The Bureau’s experience in this work is evident, however, the time may have come where the Department exercises a more clearly structured strategy.

In summary, the Team was unable to develop a correlation between accidents and particular bridge rail exposure and as a result this section is not data-driven but the result of the collective thoughts and ideas from the bridge maintenance community.

Revisiting the Level of Service Policy of Roadside Safety Barrier resulted in precisely identifying "Critical Damage", or High Priority Damage, using Tables 1, 2 and Matrix 1. An expansion of Repair Schedule Categories (adding Medium to High and Low), while also looking at reasonable part lead times, resulted in Table 3. This is a suggestion/modification to the Bridge Rail Repair Schedule within the policy. These mechanisms should make identifying critical issues more clear and establish good reasonable repair schedules.

An In-Place Bridge Rail replacement strategy is suggested. The collective thoughts of the bridge maintenance community articulate suggestions in prioritizing retrofitting or replacing bridge rail systems. Replacing the oldest aluminum and concrete rail first, with considerations of location (highway & bridge geometry, speed & AADT), condition, upcoming/future work plans (synergy) and funding is a good goal. These are best evaluated by the Departments' teams that are currently charged with annual site visits. Finally, a consideration of Retrofitting/Replacement alternatives is presented. Over time, this more structured proposal will benefit public safety and address risk for the Department.

SECTION 5

Existing Guardrail Adjustments in Policy, Design and Maintenance

Guardrail Repair Level-of-Service:

MaineDOT has an existing Level of Service policy for its Roadside Safety Barriers (included in the appendix) that dictates repair within a time frame of 1 to 6 weeks, depending upon the nature of the damage and the priority of the corridor. However, the Department's current process for identifying, documenting and repairing the impacted assets is not sufficient to determine whether the current level-of-service standards are being met. It is therefore recommended that the process be revisited and reviewed for efficiency, consistency and measurability statewide.

In addition, it is recommended that guardrail inspections be included in a statewide Maintenance Quality Assessment program where a portion of the network is sampled and inspected on an annual basis to provide a gauge of how guardrail condition and repair, among other maintenance items, can be compared across priority corridors and regions of the state.

Retrofits:

There are approximately 14,000 guardrail assets along state maintained corridors with roughly 28,000 end treatments that include radius beam, crash ends, bridge attachments and connections to other assets. Although there are numerous guardrail standards represented across the statewide inventory, it is neither necessary nor cost-effective to upgrade everything to the most recent standard. However, there are a few outdated systems, end treatments and issues that would be reasonable to prioritize, fund and upgrade on a schedule more immediate than the normal replacement cycle. These include the following:

- *Turn-down end treatments* – replace any that may be exposed to errant vehicles traveling at speeds in excess of 30 MPH.
- *Old-Style Cable Rail* – Prioritize and upgrade any areas where this still exists
- *Scenic/COR-TEN Guardrail* - Prioritize and upgrade any areas where beam has started to rust through
- *Guardrail Asset and End Treatment Elimination* – Since guardrail itself, as well as guardrail end treatments, create their own hazard (albeit, a lesser hazard than what they are intended to protect), removal of any unnecessary guardrail or crash ends should remain a continuous part of the guardrail review and prioritization process.

Training:

Due to the complexity of the various crash end systems, the following is recommended to help better identify issues that may impact the performance of a crash end:

- Enhance the current M&O Data Collection Manual (Asset Inventory Manual) to provide clearer guidance on identifying crash ends.

- Provide additional training to field personnel to help them better identify crash ends and recognize the critical installation and repair issues. Web-based videos, by crash end type, may be the most convenient and practical with consideration of the statewide distribution of the personnel and the amount of workforce turn-over.

SECTION 6

Miscellaneous Items – Local Bridges, General Poor Condition Bridge Rails

LOCAL BRIDGES, GENERAL POOR CONDITION BRIDGE RAILS

There are many structures not owned by the State of Maine. These are generally owned by municipalities, and are priority 6 corridors. The current process for MaineDOT maintenance on structures not owned by the State of Maine concludes with a "Bad Bridge Letter" to the municipality if there is a reported deficiency. Department Bridge Maintenance Inspectors report such issues directly to the Assistant Bridge Maintenance Engineer who formalizes the letter mentioned above.

The Department offers expertise and opinion for discussing remediation options, but provides no engineering to the town. The Municipality is responsible for finding and implementing a solution. The MaineDOT will sometime provide a standard bridge rail detail. The consequence for not addressing a bad bridge letter is a clear liability for the town.

As mentioned earlier in Section 4, Bridge Approach Rail Maintenance and retrofit is currently addressed in an internal publication, MaineDOT Bridge Maintenance Standards, BR 603 Bridge Approach Rail Maintenance. This Standard will be refreshed in the near future as the last revision was internally published on 8/14/01. If a local bridge approach rail is determined a safety issue, the municipality will be notified in writing of the deficiencies.

Bridge Maintenance will consider enhancing a "Bad Bridge Letter". Possibilities include a brief paragraph establishing the bridge rail system is part of the liability, perhaps a set of photos clarifying the concern. Although the current letter is adequate and the Department enjoys Sovereign immunity regarding civil or criminal suits, the optics or public opinion could affect Legislature view. According to legal counsel, the more direct and specific items addressed in a letter to the municipality, the better the situation is for the Department. A reasonable balance needs to be reached here.

SECTION 7

Preparing for MASH Requirements & Implementation

Highway Program Preparation for MASH requirements

The AASHTO/FHWA Joint Implementation Agreement outlines three areas where state agencies are given responsibility for implementing a MASH compliance transition plan.

1. *Agencies are urged to establish a process to replace existing hardware that is not NCHRP 350 compliant.*

   The Guardrail and Guardrail Terminal Policy will address when hardware must be replaced on roadway projects. See the discussion in the next section for more detail.

   Many sections of roadway are unlikely to see a roadway project in the foreseeable future. There are several systems in place that are not NCHRP 350 compliant – MELTs, BCTs, and "turn-downs". It is recommended to review the turndown locations identified in MATS as soon as possible to determine our risk if left in place. The department should fund a replacement program in the next 3 year work plan. It is estimated replacement of all turndowns would cost $250,000. It is further recommended to include replacement of all MELT and BCT guardrail ends in capital improvement projects including preservation projects. It is estimated that approximately 300 of these assets per year are within the work area for projects. Our Guardrail Policy C8 should be adjusted accordingly.

2. *Agencies are encouraged to upgrade existing hardware to MASH compliance when a system is damaged beyond repair or when agency policy requires an upgrade.*

   Replacing hardware that is damaged beyond repair is typically the responsibility of Maintenance. Currently, systems are replaced in kind. This practice will continue until MaineDOT establishes that all newly installed hardware must be MASH compliant on roadway projects.

   The Guardrail and Guardrail Terminal Policy addresses when non-compliant systems must be upgraded as part of roadway projects. Currently, upgrade requirements depend on the scope of work and are based on NCHRP 350 compliance. MaineDOT will be updating this Policy to reflect the shift to the Midway Splice Guardrail (also known as the Midwest Guardrail System, or MGS). When MaineDOT establishes that newly installed terminals must be MASH compliant, the Policy will be updated again to reflect this. The updated Policy will address when terminals must be upgraded to MASH compliance and when NCHRP 350 (or lesser) compliant systems may stay in place.

3. *The agreement requires that contracts on the National Highway System that let after the following dates specify use of MASH compliant hardware.*
4.

12-31-2017	W-Beam Barrier
	Cast-in-Place Concrete Barriers
6-30-2018	W-Beam Terminals
12-31-2018	Cable Barrier/Terminals
	Crash Cushions
12-31-2019	Bridge Rail
	Bridge Transitions
	Breakaway Hardware

The following sections outline recommendations for MASH implementation by the Highway Program and the Bridge Program Project Development.

Highway Program

W-Beam Barrier

The Highway Program is taking the lead on w-beam barrier compliance. On several contracts, a MASH compliant system known as the Midway Splice Guardrail (also known as the Midwest Guardrail System, or MGS) has already been specified in place of the traditional system. Word has gone out informally that all projects that call for new guardrail installations should be using the new system unless there are valid reasons for not doing so. This effort is not limited to the National Highway System. The Program recommends that this new system be used regardless of highway system or corridor priority.

Going forward, the Highway Program should formalize the current implementation of Midway Splice Guardrail usage on all new installations, across all Programs. In order to accomplish this, the following actions need to be taken:

1. Work out several technical details, such as what post length will be appropriate in different situations
2. Develop and publish Standard Details and Specifications. This is a non-proprietary system so there are no manufacturer's details to rely on.
3. Update the Department's Guardrail and Guardrail Terminal Policy to reflect this change. During the next several years, as the deadlines pass for various hardware components to be MASH compliant, the Policy may need to be updated several times.
4. Make sure that the entire Bureau of Project Development is informed and educated

The Program will continue to investigate both proprietary systems and variations of the Midway Splice System to determine when these systems are appropriate for use. Guidance on this will either be included in the Guardrail and Guardrail Terminal Policy or will take the form of Design Guidance.

Cast-in-Place Concrete Barriers

New cast-in-place installations have been rare and this is an area that the Highway Program has not focused on. There are a number of compliant systems currently available. Use of one of these systems should be discussed on any new project requiring cast-in-place concrete barrier.

W-Beam Terminals

There are currently a limited number of compliant systems available. The Product Evaluation Committee has been evaluating new systems as they have become available and to date there is one compliant system listed on MaineDOT's Qualified Products List. Evaluation of new systems is expected to continue.

Although a few systems are available, MaineDOT should not require MASH compliant terminals prior to the deadline until at least two options can be approved for placement on the Qualified Products List.

Cable Barrier/Terminals

There are a few remaining locations where cable barrier may be installed in the near future. These should be discussed on a case by case basis. It may be preferential to install systems similar to those already in place locally for consistency and ease of maintenance. MASH compliance would only be required after the deadline.

Crash Cushions

The Product Evaluation Committee should evaluate new systems as they become available and when at least two crash cushions in a particular category get added to the Qualified Products List, consideration should be given to requiring MASH compliance before the deadline.

<u>Bridge Program Preparation for MASH requirements</u>

The AASHTO Joint Implementation Agreement for MASH requires the use of only MASH tested bridge rails and transitions for all contracts on the National Highway System (NHS) let after December 31, 2019.

For projects on the NHS in Maine, a TL-4 rated bridge rail will usually be sufficient. In some rare instances, site conditions may require the use of a TL-5 rated system. MaineDOT maintains standard details for the following TL-4 and TL-5 rated railings:

TL-4: Two Bar Steel Traffic Railing (34" height)

Three Bar Steel Traffic / Bicycle Railing (42" height)

Four Bar Steel Traffic / Pedestrian Railing (42" height)

Type IIIA Permanent Concrete Barrier (32" height)

TL-5: Type IIIB Permanent Concrete Barrier (42" height)

MaineDOT generally defaults to the standard steel bridge rail for all new bridge projects. Occasionally the permanent concrete barrier is used when site conditions warrant a solid barrier. In other situations where a more aesthetically pleasing railing is desired, MaineDOT may work with the public and FHWA to identify other crash tested rail systems that may better fit the desired aesthetic.

It is our understanding that with regard to bridge railings, the most significant difference between NCHRP 350 and MASH 2016 is with the TL-4 requirements. Crash testing to date indicates that that the minimum height required to pass a TL-4 test will be in the range of 36 inches. This would lead us to believe that the Two Bar Steel Rail and the Type IIIA concrete barrier would not pass as a MASH TL-4 system. These two systems may still qualify as a TL-3 or lower system under MASH and continue to be used as such.

To address the need for MASH TL-4 and above concrete barriers, several options already exist and more may also become tested prior to 2019. For example, TxDOT has single slope concrete barrier rails in 36" and 42" heights successfully crash tested and approved as MASH TL-4 and TL-5 respectively. As other shapes are tested, MaineDOT will select one design and update standard details accordingly.

To provide an open rail option, it is MaineDOT's desire to have the NETC style steel bridge rail evaluated under MASH. MaineDOT has reached out to other Northeast states and has found similar interest in continued use of the NETC railing. MaineDOT has submitted the NETC design for consideration under the NCHRP 20-07/Task 395 research project. The objectives of this research project are to: (1) prioritize bridge railings including concrete barrier, (2) determine MASH equivalent test levels, and (3) determine whether individual types of bridge railing could be submitted to FHWA for determination of Federal-aid reimbursement eligibility or whether retesting is needed. An initial report is expected before the end of 2016. Based on this report it will become clear how.

Appendix A – Bridge Management dB report on rail in condition state #4.

Region	Corridor P	NBI 029: A	Rail Type	Environment	Total	State1	State2	State3	State4	%in State 4	
01 - Southern - Brunswick	1	10455	Reinforced Concrete Bridge Rai	4 - Sev.	694	600	92	0	2	0%	
01 - Southern - Kittery	1	10673	Metal Bridge Railing	2 - Low	200	0	0	100	100	50%	
01 - Southern - Portland	1	5160	Metal Bridge Railing	4 - Sev.	362	358	0	0	4	1%	
02 - Mid-Coast - Bowdoinham	1	10960	Metal Bridge Railing	4 - Sev.	186	180	0	0	6	3%	
02 - Mid-Coast - Camden	1	6420	Metal Bridge Railing	4 - Sev.	56	0	54	0	2	4%	
02 - Mid-Coast - Clinton	1	8049	Metal Bridge Railing	2 - Low	340	335	0	0	5	1%	
03 - Western - Rumford	1	8860	Reinforced Concrete Bridge Rai	4 - Sev.	58	0	0	46	12	21%	11%
03 - Western - Anson	2	4070	Metal Bridge Railing	4 - Sev.	32	0	16	0	16	50%	
03 - Western - Peru	2	5270	Metal Bridge Railing	3 - Mod.	1148	806	114	114	114	10%	
04 - Eastern - Whiting	2	1942	Metal Bridge Railing	4 - Sev.	308	0	288	0	20	6%	
04 - Eastern - Whiting	2	1942	Reinforced Concrete Bridge Rai	3 - Mod.	308	0	298	0	10	3%	
05 - Northern - Fort Kent	2	2281	Metal Bridge Railing	4 - Sev.	40	36	0	0	4	10%	
05 - Northern - Presque Isle	2	9598	Metal Bridge Railing	3 - Mod.	374	336	18	18	2	1%	13%
01 - Southern - Buxton	3	2105	Reinforced Concrete Bridge Rai	4 - Sev.	8	0	6	0	2	25%	
01 - Southern - Hollis	3	4424	Metal Bridge Railing	2 - Low	417	100	100	200	17	4%	
01 - Southern - Hollis	3	4424	Metal Bridge Railing	2 - Low	1536	300	200	1000	36	2%	
03 - Western - Chesterville	3	4270	Reinforced Concrete Bridge Rai	3 - Mod.	465	0	250	150	65	14%	
04 - Eastern - Blue Hill	3	7790	Reinforced Concrete Bridge Rai	4 - Sev.	34	0	24	0	10	29%	
04 - Eastern - Dover-Foxcroft	3	2574	Metal Bridge Railing	4 - Sev.	30	0	0	27	3	10%	
04 - Eastern - Howland	3	5261	Metal Bridge Railing	2 - Low	1852	0	1000	800	52	3%	13%
01 - Southern - Bath	4	8887	Metal Bridge Railing	3 - Mod.	358	328	10	10	10	3%	
01 - Southern - Cumberland	4	3625	Reinforced Concrete Bridge Rai	2 - Low	998	980	0	0	18	2%	
01 - Southern - Harpswell	4	6323	Metal Bridge Railing	3 - Mod.	272	245	0	0	27	10%	
01 - Southern - Sanford	4	6702	Metal Bridge Railing	2 - Low	128	0	0	0	128	100%	
01 - Southern - Standish	4	2497	Metal Bridge Railing	3 - Mod.	38	0	19	0	19	50%	
02 - Mid-Coast - Bowdoin	4	2349	Metal Bridge Railing	4 - Sev.	34	0	17	0	17	50%	
02 - Mid-Coast - Dresden	4	1506	Metal Bridge Railing	3 - Mod.	592	0	224	268	100	17%	
02 - Mid-Coast - Litchfield	4	1540	Metal Bridge Railing	3 - Mod.	46	0	23	12	11	24%	
03 - Western - Andover	4	890	Metal Bridge Railing	3 - Mod.	188	0	100	80	8	4%	
03 - Western - Anson	4	3800	Metal Bridge Railing	4 - Sev.	28	0	22	0	6	21%	
03 - Western - Perkins Twp	4	710	Metal Bridge Railing	2 - Low	58	0	28	15	15	26%	
03 - Western - Weld	4	950	Reinforced Concrete Bridge Rai	3 - Mod.	90	0	85	0	5	6%	
04 - Eastern - Bangor	4	2894	Reinforced Concrete Bridge Rai	3 - Mod.	456	0	400	50	6	1%	
04 - Eastern - Jonesport	4	2508	Reinforced Concrete Bridge Rai	3 - Mod.	61	1	48	6	6	10%	23%
01 - Southern - Bath	5	2093	Metal Bridge Railing	3 - Mod.	116	0	60	40	16	14%	
01 - Southern - Buxton	5	2085	Reinforced Concrete Bridge Rai	4 - Sev.	34	0	30	0	4	12%	
03 - Western - West Paris	5	610	Metal Bridge Railing	4 - Sev.	200	0	150	0	50	25%	
04 - Eastern - Burlington	5	348	Reinforced Concrete Bridge Rai	2 - Low	46	32	10	2	2	4%	
05 - Northern - Hodgdon	5	1809	Reinforced Concrete Bridge Rai	2 - Low	56	0	50	0	6	11%	13%
01 - Southern - Acton	6	407	Metal Bridge Railing	2 - Low	40	0	0	30	10	25%	44%
01 - Southern - Acton	6	498	Reinforced Concrete Bridge Rai	3 - Mod.	44	0	29	8	7	16%	
01 - Southern - Alfred	6	98	Metal Bridge Railing	3 - Mod.	32	0	29	0	3	9%	
01 - Southern - Auburn	6	113	Metal Bridge Railing	3 - Mod.	30	0	0	0	30	100%	
01 - Southern - Berwick	6	71	Reinforced Concrete Bridge Rai	2 - Low	88	0	68	10	10	11%	
01 - Southern - Bridgton	6	112	Reinforced Concrete Bridge Rai	3 - Mod.	42	0	18	19	5	12%	
01 - Southern - Brownfield	6	84	Metal Bridge Railing	3 - Mod.	40	0	0	20	20	50%	
01 - Southern - Buxton	6	273	Metal Bridge Railing	3 - Mod.	34	0	0	0	34	100%	
01 - Southern - Buxton	6	31	Metal Bridge Railing	3 - Mod.	30	0	0	15	15	50%	
01 - Southern - Gray	6	374	Timber Bridge Railing	2 - Low	48	8	10	10	20	42%	
01 - Southern - Hiram	6	19	Metal Bridge Railing	1 - Ben.	42	0	0	0	42	100%	
01 - Southern - North Berwick	6	83	Metal Bridge Railing	2 - Low	52	0	0	26	26	50%	
01 - Southern - Oxford	6	1046	Metal Bridge Railing	3 - Mod.	28	0	14	0	14	50%	
01 - Southern - Parsonsfield	6	71	Metal Bridge Railing	1 - Ben.	44	0	0	0	44	100%	
01 - Southern - Portland	6	387	Metal Bridge Railing	2 - Low	36	34	0	0	2	6%	
01 - Southern - Pownal	6	178	Metal Bridge Railing	2 - Low	60	50	5	0	5	8%	
01 - Southern - Sanford	6	291	Metal Bridge Railing	2 - Low	30	0	0	0	30	100%	
01 - Southern - Stoneham	6	18	Metal Bridge Railing	2 - Low	42	0	0	0	42	100%	
02 - Mid-Coast - Albion	6	65	Reinforced Concrete Bridge Rai	3 - Mod.	30	0	25	0	5	17%	
02 - Mid-Coast - Unity	6	29	Timber Bridge Railing	2 - Low	168	0	0	0	168	100%	
02 - Mid-Coast - Warren	6	1907	Reinforced Concrete Bridge Rai	3 - Mod.	46	0	41	0	5	11%	
03 - Western - Andover	6	40	Metal Bridge Railing	4 - Sev.	30	0	15	0	15	50%	
03 - Western - Anson	6	290	Metal Bridge Railing	2 - Low	32	0	26	0	6	19%	
03 - Western - Bingham	6	54	Reinforced Concrete Bridge Rai	2 - Low	68	0	43	15	10	15%	
03 - Western - Blanchard Twp	6	69	Reinforced Concrete Bridge Rai	3 - Mod.	30	0	15	0	15	50%	
03 - Western - Buckfield	6	390	Reinforced Concrete Bridge Rai	3 - Mod.	34	30	0	0	4	12%	
03 - Western - Chesterville	6	193	Timber Bridge Railing	2 - Low	42	0	0	0	42	100%	
03 - Western - Concord Twp	6	84	Metal Bridge Railing	2 - Low	100	0	90	0	10	10%	
03 - Western - Gilead	6	50	Metal Bridge Railing	2 - Low	72	0	70	0	2	3%	
03 - Western - Gilead	6	90	Reinforced Concrete Bridge Rai	2 - Low	42	0	19	18	5	12%	
03 - Western - Gilead	6	50	Other Bridge Railing	2 - Low	38	0	0	0	38	100%	
03 - Western - Hartford	6	64	Metal Bridge Railing	2 - Low	66	0	0	33	33	50%	
03 - Western - Industry	6	113	Reinforced Concrete Bridge Rai	2 - Low	64	20	20	20	4	6%	
03 - Western - New Portland	6	90	Metal Bridge Railing	2 - Low	74	0	37	32	5	7%	
03 - Western - Paris	6	440	Metal Bridge Railing	2 - Low	30	0	20	0	10	33%	
03 - Western - Rangeley	6	200	Metal Bridge Railing	2 - Low	142	0	0	0	142	100%	
03 - Western - Sumner	6	109	Metal Bridge Railing	2 - Low	60	0	0	36	24	40%	
03 - Western - Sumner	6	103	Metal Bridge Railing	2 - Low	48	0	0	43	5	10%	
03 - Western - Wilton	6	173	Reinforced Concrete Bridge Rai	1 - Ben.	96	0	91	0	5	5%	
04 - Eastern - Bangor	6	1840	Metal Bridge Railing	3 - Mod.	602	580	20	0	2	0%	
04 - Eastern - Carmel	6	75	Metal Bridge Railing	2 - Low	50	0	40	5	5	10%	
04 - Eastern - Carmel	6	21	Metal Bridge Railing	2 - Low	62	0	0	0	62	100%	
04 - Eastern - Centerville	6	69	Metal Bridge Railing	3 - Mod.	42	0	0	0	42	100%	
04 - Eastern - Dennysville	6	234	Reinforced Concrete Bridge Rai	2 - Low	210	186	20	0	4	2%	
04 - Eastern - Mariaville	6	60	Metal Bridge Railing	2 - Low	50	0	0	25	25	50%	
04 - Eastern - Parkman	6	10	Timber Bridge Railing	1 - Ben.	40	0	0	0	40	100%	
04 - Eastern - Whiting	6	29	Reinforced Concrete Bridge Rai	1 - Ben.	136	0	0	0	136	100%	
05 - Northern - Island Falls	6	261	Reinforced Concrete Bridge Rai	2 - Low	116	0	75	25	16	14%	
01 - Southern - Naples	Unk	0	Reinforced Concrete Bridge Rai	2 - Low	218	0	163	45	10	5%	

Appendix B - State of Maine Department of Transportation Bridge Maintenance Standards, specifically BR 603 Bridge Approach Rail Maintenance.

The following pages of this Appendix are part of the State of Maine Department of Transportation Bridge Maintenance Standards, specifically BR 603 Bridge Approach Rail Maintenance.

This document provides guidance for the Bureau of Maintenance & Operations how Approach Rail is addressed when major maintenance is performed on a bridge in different situations.

The last revision of this Standard was published internally in 2001 and will be refreshed by Bridge Maintenance in the near future. The main issues will remain and congruent with Department Policy regarding local bridges as well as using good engineering judgment.

- State owned bridges on state roads/highways will receive “4 corners” of approach rail when determined necessary.

- State owned bridges on town ways will address the issue of the “4 corners” of approach rail and notify in writing municipalities this effort needs to be accomplished.

- Local bridges on town ways will continue to be part of the [Local] “Bad Bridge Letter” notifying municipalities of issues including insufficient bridge rail and approach rail.

Date: April 29, 1998
[Last Revis.: N.A.]
[Orig. Issue: N.A.]

STATE OF MAINE

DEPARTMENT OF TRANSPORTATION
Bureau of Maintenance & Operations
Bridge Maintenance Division

Bridge Maintenance Standard

BR 603

Bridge Approach Rail Maintenance

Purpose:

The main purpose of these guidelines is to provide a standard practice for obtaining satisfactory transition approach guard rail sections when Bridge Maintenance performs major maintenance on a bridge.

Guidelines:

When major maintenance is performed on a bridge, the approach guard railings shall be improved to an acceptable condition with beam guard rail as follows:

1. Ending a transition approach beam guard rail with a straight section is not acceptable.

2. Since Bridge Maintenance does not have primary responsibility for approach maintenance, than our policy will be to provide a minimum 25 foot length of a beam guard rail system per bridge corner when the agency that has this responsibility can not do the work (See **Appendix A**).

Highway Maint in 2001

3. If an existing approach "cable" guard rail system is much longer than 25 feet, than it should be reattached to the bridge **in addition to** a new beam guard rail placement as shown in **Appendix A**, Sheet 1 of 2.

4. The following approach beam guard rail attachment systems to a bridge are acceptable:

a. A "Michigan Shoe" attachment system may be made if the existing bridge end posts are large enough. Modifications may be made to either the "Shoe" or the existing end post, or both.

b. If existing bridge end posts can not be satisfactorily modified for attachment of beam guard rail, than new concrete end post replacements recessed for standard beam guard rail will be constructed. Beam guard rail may be carried across bridges less than 20 feet in length.

c. If there are no existing bridge end posts and bridge end posts can not be constructed, than an appropriate attachment of the beam guard rail will be made to some portion of the existing bridge structure. If this attachment "projects" into the roadway "clear zone", than a "Michigan Shoe"-type connection should be made.

5. Plans for modifying or replacing concrete end posts may be obtained upon request from the Augusta Bridge Maintenance Office.

Bridge Approach Rail Maintenance: (Townways)

When Bridge Maintenance performs major work repairs on state bridges on town ways, the Division Bridge Maintenance Manager shall be responsible for contacting the municipality to advise them of the work that is anticipated. The Manager should give the municipality the opportunity to provide satisfactory approach guard rail improvements, as previously detailed, immediately following our work.

WCE/wce

Appendix A

MDOT,
Br. Maint. Div.

<u>"BRIDGE APPROACH RAIL -
3 Cable, (2 Cable) Rail Transition"</u>

(Sheet 1 of 2)

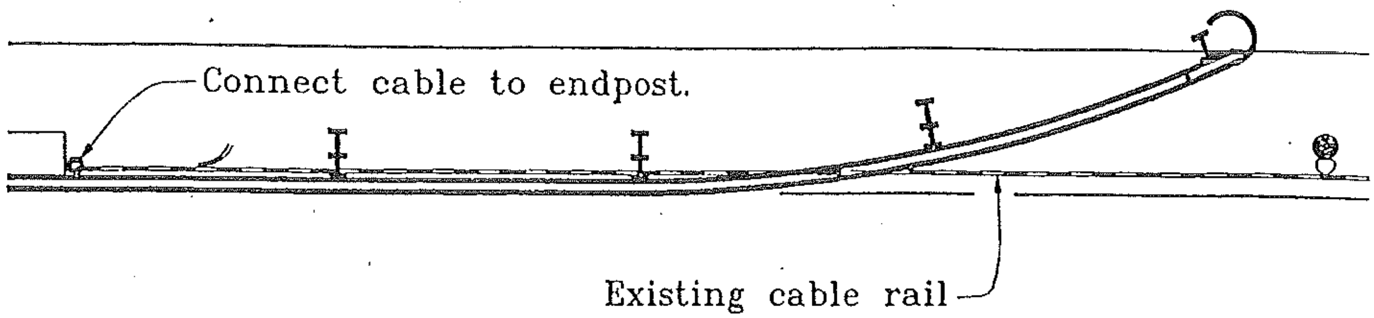
and

<u>"BRIDGE APPROACH RAIL -
Beam Guard Rail Layout"</u>

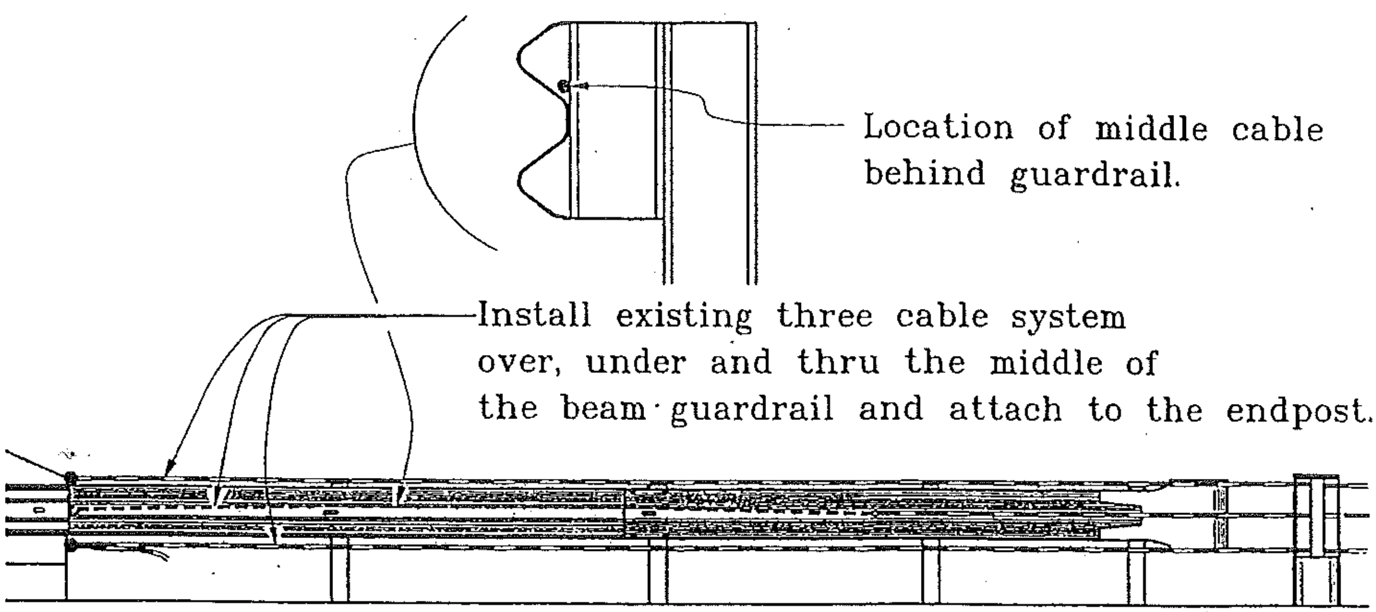
(Sheet 2 of 2)

WCE/wce

APPENDIX A



PLAN VIEW OF BEAM GUARDRAIL WITH EXISTING CABLE RAIL



ELEVATION VIEW OF BEAM GUARDRAIL W/ EXIST. CABLE RAIL

NOTES:

1...Layout of beam rail to be as shown on sheet 2 of 2.

2...Two cable rail system to be installed similar to three cable. No cable shall go thru guardrail however, only over and under.

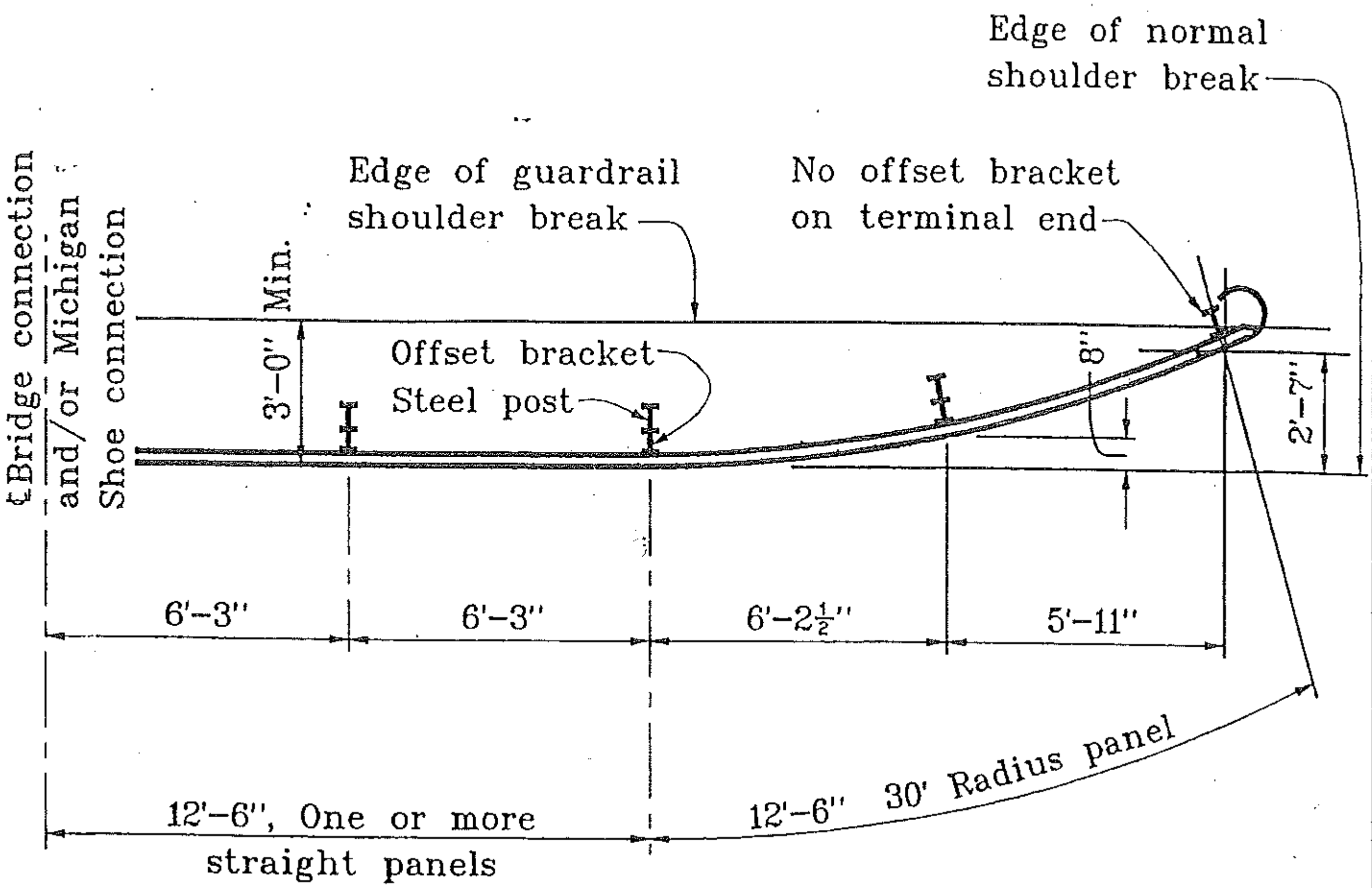
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

BRIDGE MAINTENANCE DIVISION
BRIDGE STANDARD BR603

BRIDGE APPROACH RAIL
3 Cable, (2 Cable) Rail
Transition

Sheet 1 of 2 Jan. 1998

APPENDIX A



PLAN

NOTES:

1...Layout dimensions are measured to the face of the guardrail beam.

2...Provide plate washers FWR03 for the beam-to-post connection.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

BRIDGE MAINTENANCE DIVISION
BRIDGE STANDARD BR603

BRIDGE APPROACH RAIL

Beam Guard Rail Layout

Sheet 2 of 2 Jan. 1998

Appendix C - Photos – Corten rail, old cable rail

Weathered Steel w-beam rail sequence of level of corrosion at laps.




State Rte 113
Exit Street View
© 2016 Google
© 2016 Google
Google earth
Report a problem
44°02'24.81" N 70°59'40.65" W elev 410 ft eye alt 418 ft

Appendix D - References

http://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/#prret

W-Beam Guardrail Repair: A Guide for Highway and Street Maintenance Personnel, Report No. FHWA FHWA-SA-08-002, August 2008

NCHRP Report 656, Criteria for Restoration of Longitudinal Barriers, Hampton C. Gabler, Douglas J. Gabauer, Carolyn E. Hampton, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, 2010

Appendix E - SURVEY QUESTIONS FOR STATE DOT'S

<u>Highway Guardrail Questions (includes guardrail end treatments, crash cushions/attenuators)</u>

1. Does your state have a maintenance program in place to periodically inspect existing guardrail items?
2. Has your state identified any guardrail systems that due to crash performance or maintenance issues (durability, expensive repair, etc.) have been discontinued and/or replaced? If so, please provide details.
3. Does your state have a systemic, risk-based approach to identify guardrail issues and to use this information for data-driven replacement and repair strategies? (do you have a formal process to identify issues and prioritize replacement). If Yes, please provide a description.
4. Does your state have a guardrail level of service repair strategy? (how soon are guardrail systems repaired after damage). If Yes, please provide details.
5. Does your state have a MASH implementation plan for guardrail items? If yes, please

<u>Bridge Rail Questions (includes transitions to guardrail on approaches)</u>

1. Does your bridge inspection program include specific requirements for bridge rail and transitions (this would be in addition to standard inspections per NBIS)?
2. Has your state identified any bridge rail systems that due to crash performance or maintenance issues (durability, expensive repair, etc.) have been discontinued and/or replaced? If so, please provide details.
3. Does your state have a systemic, risk-based approach to identify bridge rail issues and to use this information for data-driven replacement and repair strategies? (do you have a more formal process to identify issues and prioritize replacement). If Yes, please provide a description.
4. Does your state have a bridge rail level of service repair strategy? (how soon are rail systems repaired after damage). If Yes, please provide details.
5. Does your state have a MASH implementation plan for bridge rail? If Yes, please provide a copy.

Appendix F – Chief Engineer Memo to Commissioner to Study Guardrail and Bridge Rail Risks

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

Paul R. LePage
GOVERNOR

David Bernhardt
COMMISSIONER

To: David Bernhardt, Commissioner

From: Joyce Noel Taylor, PE; Chief Engineer JNT

Date: April 28, 2016

Re: Proposal to Study Guardrail and Bridge Rail Risks

Cc: Core Group

MaineDOT recently affirmed through an AASHTO ballot its support for the new MASH standards related to crash testing of guardrail, bridge rail and offer types of barriers. MaineDOT also has recently evaluated a specific system related to end barriers and is continuing a research project to gather data on the condition of other end barrier systems. The Bureau of Maintenance and Operations is evaluating a specific bridge rail system to determine condition ratings. The Engineering Council is proposing to update its policy to adopt the MASH standards. There is some synergy in the various efforts that lead me to propose a research project to gather information so MaineDOT can make data driven decisions prior to updating our policy on barrier replacements.

I propose sponsoring a team to do the following:

- Collect information from other States including policies on barrier retrofits and removals.
- Formulate a plan to gather data in Maine on installation accuracy and current maintenance efforts.
- Evaluate the barrier systems used in Maine and identify risks associated with various systems.
- Prioritize barrier systems that should be replaced and updated. This might lead to an annual barrier retrofit or replacement project in the work plan.
- Make recommendations to update the Guardrail and Guardrail Terminal Policy
- Make recommendations on maintenance of systems.

The team will be led by Dale Peabody, Director of Research. Atlee Mousseau is another person who is knowledgeable in this area. I want to name him as the Assistant Team Leader. I think they will need five to six other people to assist. Representation shall come from Bridge Maintenance, the Bridge Program, the Highway Program and another representative from the Bureau of M&O. I would like to add two Assistant Engineers we can devote to this effort. This team shall report out its results by August 31, 2016 so the information can be used prior to the next work plan.