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REPORT

Ministry of Forest and Range

Phase II
Development of MFR Standard Curb Design Parameters Barrier Selection and Design Philosophy

March 2011

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1 Introduction

Although the CAN/CSA-S6-06, Canadian Highway Bridge Design Code (CHBDC) is a primary reference for forest road bridge design, the bridge barrier design requirements do not directly relate to industrial forest road bridge curb design. As a result, the MNRO retained Associated Engineering to assist in the development of appropriate bridge barrier design guidelines, including specified design parameters, for Forest Service Road bridge barriers.

In Phase 1 of this project, we reviewed existing literature regarding current practices for the design and installation of bridge barriers on low volume and forestry road bridges in North America. This Phase, Phase 2, presents a proposed *Barrier Selection and Design Philosophy*. We have based the proposed philosophy on the previously completed literature review and current MNRO practices.

The literature review highlighted the following with respect to the selection and design of bridge barriers on forest roads:

.1 With the exception of the Ontario Ministry of Natural Resources (MNR), no regulatory agencies specifically address the containment of off-highway or industrial traffic. Further, the MNR Crown Land Bridge Management Guidelines state in Clause 4.1.5. *"Curbs and railings need not be designed to withstand live loads specified in the Bridge Code. They are intended to mark the edge of the bridge deck and need not be designed to deflect an impacting vehicle."* The inclusion of this Clause is a recognition by the MNR that it is not practical to try to contain heavy industrial traffic.

.2 Within Canada, the British Columbia Ministry of Transportation and Infrastructure requires the installation TL-2 barriers on publicly accessed low volume roads although they do allow the installation of TL-1 barriers where very low traffic volumes are expected (ADT < 50). The Ontario Ministry of Transport has developed warrants for bridge barriers on low volume roads that allow for the installation of TL-1 (LVPL2) and lower level barriers (LVPL1) where specific criteria are met. These criteria include reduced traffic volumes, limiting design speeds, reduced bridge width and height above water.

.3 With the exception of the Ontario Ministry of Natural Resources and the MNRO, all jurisdictions, for which information was available, require the installation of crash tested bridge barriers in accordance with NHCRP 350 – "Recommended Procedures for the Safety Performance Evaluation of Highway Features". This report was recently superseded by an AASHTO publication, the "Manual for Analysis of Safety Hardware (MASH)". Both AASHTO LRFD and MASH divide bridge barriers into six Test Levels. We understand that the CHBDC will be adopting these six Test Levels in future editions. Each Test Level corresponds to a certain level of barrier performance, with TL-1 being a low performance barrier for use on low volume local roads, and TL-6 being a very high performance barrier. **Table 1-1** provide subjective descriptions for each performance level.

Neither of these documents provides criteria for selecting a performance level and they rely on the regulatory authorities to specify the minimum required performance levels. Table 1-2 summarizes the crash test criteria for performance level TL-1 and TL-2 barriers, the most commonly prescribed barriers for low volume roads.

Table 1-1
AASHTO Guidelines for Intended Use of Barrier Test Levels

Test Level	Intended Use
TL-1	For work zones with low posted speeds and very low volume, low-speed local streets.
TL-2	For work zones with moderate speeds or with small number of heavy vehicles at reduced speeds and most local and collector roads with favourable site conditions
TL-3	For a wide range of high-speed arterial highways with low mixtures of heavy vehicles and with favourable site conditions.
TL-4	For the majority of applications on high-speed highways, freeways and expressways with a mixture of trucks and heavy vehicles
TL-5	For the same site conditions as TL-4 when the site conditions justify a higher level of rail resistance and for applications on freeways with high-speed, high-traffic volumes and where trucks make up a significant portion of the traffic or when unfavourable site conditions exist.
TL-6	For applications on freeways with high-speed, high-traffic volumes and a higher ratio of heavy vehicles and a highway with unfavourable site conditions.

Table 1-2
MASH Crash Test Criteria for TL-1 and TL-2 Barriers

Test Level	Test Vehicle	Vehicle Mass lb. (kg)	Impact Speed mph (km/h)	Impact Angle Degrees
TL-1	Intermediate Car	3300 (1500)	31 (50)	25
	Pick-up Truck	5000 (2270)	31 (50)	25
TL-2	Intermediate Car	3300 (1500)	44 (70)	25
	Pick-up Truck	5000 (2270)	44 (70)	25

In presenting the two performance levels in **Table 1-2**, we note that

- The TL-1 and TL-2 Test Levels are appropriate based on the vehicle types, as the 'intermediate car' and 'pickup truck' categories will encompass essentially all traffic except for industrial vehicles on resource roads.

Off-highway logging truck crossing a 4.8 m wide bridge

- The heaviest test vehicle used for MASH crash testing (of high performance vehicles) is a 36,000 kg tractor-tank trailer. As off-highway logging vehicles can range in mass from 68,000 kg to 149,700 kg, it is unlikely that even the highest performance crash-tested barrier will perform (as required by MASH) adequately in a real crash scenario.

- MASH addresses safety hardware for use on highways and public roads. The design of these roads includes other issues that address safety, such as sightlines, super-elevation limits, approach barrier configuration, lane widths and shoulder widths, among other factors. The MASH barrier test levels and their associated performance requirements account for consideration of these factors, which may not be as thoroughly considered for resource roads and bridges.

- The MASH parameter for impact angle appears to be inappropriate for resource bridges, which are typically designed for single lane traffic, and are considerably narrower than typical urban low volume bridges. As such, achievement of a 25° impact angle at design speeds of 50 km/h and 70 km/h is unlikely.

.4 The US Forest Service recommends the installation of TL-1 bridge barriers on Maintenance Level 2 Roads, i.e., roads open for use by high clearance vehicles (industrial traffic) where passenger car traffic is not a consideration. **Table 1-3** summarizes the US Forest Service barrier selection criteria.

Table 1-3
Minimum Bridge Barrier Requirements on US National Forest Service Roads

Objective Maintenance Level (ML)	Minimum Required Test Level (TL)
ML 1: These are roads that have been placed in storage between intermittent uses. Basic custodial maintenance is performed to prevent damage to adjacent resources and to perpetuate the road for future resource management needs. Emphasis is normally given to maintaining drainage facilities and runoff patterns. Planned road deterioration may occur at this level. Appropriate traffic management strategies are "prohibit" and "eliminate" all traffic. These roads are not shown on motor vehicle use maps. Roads receiving Level 1 maintenance may be of any type, class, or construction standard, and may be managed at any other maintenance level during the time they are open for traffic. However, while being maintained at level 1, they are closed to vehicular traffic but may be available and suitable for non-motorized uses.	TL-1
ML 2: Assigned to roads open for use by high clearance vehicles. Passenger car traffic, user comfort, and user convenience are not considerations. Warning signs and traffic control devices are not provided with the exception that some signing, such as W-18-1 "No Traffic Signs," may be posted at intersections. Motorists should have no expectations of being alerted to potential hazards while driving these roads. Traffic is normally minor, usually consisting of one or a combination of administrative, permitted, dispersed recreation, or other specialized uses. Log haul may occur at this level. Appropriate traffic management strategies are either to discourage or prohibit passenger cars, or accept or discourage high clearance vehicles.	TL-1
ML 3: Assigned to roads open and maintained for travel by a prudent driver in a standard passenger car. User comfort and convenience are not considered priorities. The Manual on Uniform Traffic Control Devices (MUTCD) is applicable. Warning signs and traffic control devices are provided to alert motorists of situations that may violate expectations. Roads in this maintenance level are typically low speed with single lanes and turnouts. Appropriate traffic management strategies are either "encourage" or "accept." "Discourage" or "prohibit" strategies may be employed for certain classes of vehicles or users.	Design Speed: < 50 km/hr: TL-1 > 50 km/hr: TL-2

Objective Maintenance Level (ML)	Minimum Required Test Level (TL)
ML 4: Assigned to roads that provide a moderate degree of user comfort and convenience at moderate travel speeds. Most roads are double lane and aggregate surfaced. However, some roads may be single lane. Some roads may be paved and/or dust abated. Manual on Uniform Traffic Control Devices is applicable. The most appropriate traffic management strategy is "encourage." However, the "prohibit" strategy may apply to specific classes of vehicles or users at certain times.	TL-3
ML 5: Assigned to roads that provide a high degree of user comfort and convenience. These roads are normally double lane, paved facilities. Some may be aggregate surfaced and dust abated. Manual on Uniform Traffic Control Devices is applicable. The appropriate traffic management strategy is "encourage."	TL-3

.5 The AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) suggests that a risk based design approach for low volume roads is acceptable given:

- The very low traffic volumes, encounters between vehicles that represent opportunities for crashes to occur are rare events and that multiple-vehicle collisions of any kind are extremely rare events.
- The local nature of the road means that most motorists using the road have traveled it before and are familiar with its features i.e. geometric design features that might surprise an unfamiliar driver will be anticipated by the familiar driver.

Further, the Guide defines a rural resource recovery road as *"...local roads serving logging or mining operations. Such roads are typically found only in rural areas. Resource recovery roads are distinctly different from the other functional subclasses of very low-volume local roads in that they are used primarily by vehicles involved with the resource recovery activities and the driving population consists or exclusively of professional drivers with large vehicles. In some cases, traffic operations on resource recovery roads are enhanced through radio communication between drivers, enabling such roads to be built and to operate as single-lane roads. Most resource recovery roads are unpaved."*

In addition, we are able to define the following unique characteristics related to MNRO roads and bridges:

- Roads and bridges built by the MNRO primarily serve the resource sector, and are designed as such. Roads are typically unpaved, and bridges are typically narrower than urban bridges.
- Roads routinely see Average Daily Traffic below 400 vehicles per day, most of which are heavy industrial vehicles, construction equipment, pick-up trucks and service vehicles, driven by trained drivers or workers familiar with the road conditions and applicable operational protocols.
- Roads are not designed and built to the same level of "general safety" as roads that see higher traffic volumes or a higher percentage of public traffic.
- Typical bridge barriers specified by other jurisdictions and those currently used by the MNRO are not capable of containing heavy industrial traffic.
- A small percentage of MNRO roads also provide access to communities, or a recreational attraction, and therefore may see increased public vehicle and/or pedestrian use. These bridges may be single or double-lane, and some users may not be as familiar with the driving conditions or the operational protocol.

2 Recommended Approach to the Selection of Bridge Barriers

As discussed in the previous section, there is a varied approach to the selection and design of bridge barriers for bridges on forestry roads. Most regulatory agencies that govern **public roads** require as a minimum the installation of TL-1 or TL-2 performance level barriers on low volume roads. Notwithstanding, we believe that it is appropriate to adopt a risk based approach to the selection of bridge barriers. This approach would be similar to that described for the geometric design of low volume roads incorporated in AASHTO's "*Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)*". In addition, we recognize that the MNRO standard bridge barriers appear to be performing adequately and provide an acceptable level of containment.

In developing a risk-based evaluation and selection criteria, the MNRO will need to assess the risks associated with the following factors at each bridge location.

Anticipated Traffic Volume

The higher the traffic volumes, the higher the probability that a vehicle will impact the bridge barrier. Typical limits for low volume roads are an ADT ≤ 400 vehicles per day and most forestry roads experience significantly less than 400 vehicles per day.

Anticipated Traffic Mix

Where public access is limited, the MNRO can reasonably expect that road users will be familiar with the road and associated travel conditions. Further, operators of these roads will likely have safety protocol in place that governs the use of the road and it may therefore be appropriate to accept a lower level of containment. However, on roads where the MNRO anticipate a higher proportion of public traffic, we recommend consideration be given to providing a higher level of containment, since road users may not be familiar with the road and associated road conditions, and hence are more vulnerable to accidents.

Poor horizontal and vertical alignment and increased bridge width

Horizontal and Vertical Alignment

The bridge alignment affects the probability that a vehicle may lose control and require containment along the bridge. Vehicles are more likely to impact barriers on bridges located on steep grades or corners.

Speed

Where the MNRO anticipates higher travel speeds, it may be appropriate to consider providing higher levels of containment. Typical limiting traffic speeds for low volume or industrial roads before increased levels of containment are required range from 50-60 km/hr.

Height

Where the bridge is located above a water body, ravine or another roadway/railway (overpass), the MNRO should consider the consequence to both the driver and surrounding environment if the vehicle breaches the barrier. Typical limiting heights above water before increased levels of containment are required range from 2.5-5.0 m. On recently designed highway overpass structures, we have incorporated TL-3 cast-in-place concrete barriers.

Bobtail FSR highway overpass

Bridge Width

Typically, the angle of incidence for a vehicle striking a barrier on a single lane bridge is low resulting in reduced containment forces. However, as the bridge width increases, the angle of incidence increases resulting in higher containment forces. Therefore, the MNRO should consider providing higher levels of containment on wider or multi-lane bridges.

Environmental Conditions and Seasonality

The MNRO should consider local conditions that may affect bridge deck or road approach conditions. These may include bridges that may receive limited sunlight and remain icy for significant portion of the day resulting in an increased likelihood of an accident on the bridge or its approaches. Where this presents a risk, the MNRO should consider providing higher levels of containment.

Pedestrians

Where the MNRO expects that a large number of pedestrians will use a bridge, the MNRO should consider providing pedestrian height rails and possibly providing increased levels of containment. Alternatives may also include a separated pedestrian sidewalk or the inclusion of pedestrian refuges on longer bridges.

Pedestrian Refuge Bay

The MNRO will need to develop objective decision-making tools to ensure consistent application of these assessment criteria throughout the Province for new bridge design and bridge replacement projects. We therefore recommend categorizing MNRO bridges into categories and establishing barrier performance requirements for each level. The following provides some guidance on how the MNRO may wish to categorize bridges that primarily service the forestry (resource) sector assuming three distinct classifications:

Category I:

This category would include bridges where the MNRO believes that the current level of containment is appropriate. Characteristics of these bridges may include:

- Relatively low height above water.
- Good vertical and horizontal alignment.
- No public or pedestrian traffic.
- Normal operating speeds.

For Category 1 bridges, the MNRO would accept the existing standard bridge barriers. We anticipate that the majority of the MNRO's bridge inventory will fall within this category.

Category II:

This category would include bridges where the MNRO believes that an increased level of containment is appropriate. Characteristics of these bridges may include:

- Limited public and pedestrian use, where users may be unfamiliar with the route and associated hazards.
- Significant height above water and/or near a significant hazard.
- Adverse geometry and / or visibility.
- Increased deck width.
- Increased operating speeds.

For Category 2 bridges, the MNRO may consider mandating the installation of TL-1 barriers, in accordance with AASHTO LRFD 2010. In making this recommendation, we believe that through static testing and field evaluation, the MNRO may be able to argue that the standard MNRO steel HSS rail barrier (MNRO Standard Drawing STD-E-010-06) is equivalent to a crash-tested TL-1 barrier.

Category III:

This category would include bridges where the MNRO believes a high level of containment is required. Characteristics of these bridges may include:

- High level of public and / or pedestrian use (may provide access to recreation destinations, or rural communities, and may see a significant proportion of drivers who are unfamiliar with the driving conditions.
- Significant height above water.
- Adverse geometry and / or visibility.
- Increased deck width or multi-lane bridge.
- High operating speeds.

For Category 3 bridges, the MNRO may consider mandating the installation of TL-2 barriers, in accordance with AASHTO LRFD 2010. In making this recommendation, the MNRO may be required to adopt a top mounted bridge barrier for precast concrete deck bridges since the capacity of the barrier is limited to the strength of the connection to the deck edge.

Appendix A contains a sample warrant from the US Forest Service illustrating the incorporation of these factors into barrier selection.

2.1 Approach Barriers

Approach barriers are intended to guide vehicles safely onto the ends of bridges. Currently, the MNRO does not require approach barriers for resource bridges. The Ontario Ministry of Natural Resources recommends that approach barriers be considered for bridges with any of the following conditions:

- Significant height.
- Poor horizontal or vertical alignment.
- Narrow deck width.
- Significant length.
- High speeds.
- High traffic volumes.

Approach barriers on a heavily trafficked bridge with significant public usage

In contrast, the US Forest Service requires the installation of approach barriers designed in accordance with a formula presented in AASHTO "Roadside Design Guide". For an ADT not exceeding 400 VPD, and a maximum design speed of 50 km/h, the US Forest Service recommends an approach barrier length of 25 ft (7.6 m). For a design speed exceeding 50 km/h, the US Forest Service recommends a length of 37.5 ft (11.4 m).

Given that anecdotal evidence suggests that on the majority of accidents on forest road bridges, the vehicle lost control on the bridge approach rather than on the bridge deck, the MNRO may wish to recommend the installation of approach barriers on bridges where

- The bridge approach has significant curvature.
- The embankments are significantly high.
- High headwalls.

Further, for an approach to be effective, it needs to be continuous with the bridge barrier to provide effective containment. Where the MNRO deems approach barriers necessary, we recommend the development of appropriate details to connect the approach barriers to the bridge barrier to provide the required continuity.

3 Recommended Approach to the Design of Bridge Barriers

As described in Section 1, with the exception of the Ontario Ministry of Natural Resources and the MNRO, all jurisdictions require the installation of crash tested bridge barriers. To address this requirement most regulatory authorities mandate the installation of standard barriers for which crash testing information is available and engineers are not required to design bridge barriers, although for some applications, they may modify or design the barrier connection to the bridge deck. Notwithstanding, the Ontario Ministry of Natural Resources and the MNRO provide standard bridge barrier details for use on their bridges while still allowing engineers to develop alternative bridge barrier details. However, in developing these alternative barriers, the MNRO provides no guidance regarding design, while the Ontario Ministry of Natural Resources clearly states that bridge barriers only provide deck edge delineation.

We recommend that the MNRO mandate the use of standard bridge barriers to ensure minimum specified levels of containment are provided. Should the MNRO allow the development of alternative bridge barriers, we recommend the development of guidelines to facilitate barrier design. In its most simplistic form, the MNRO could base these guidelines on a structural evaluation of the barrier using MNRO specified loads. Since the MNRO's standard bridge barriers provide less containment than the lowest performance level included in AASHTO LRFD and MASH, the MNRO will need to develop suitable design loads. To ensure equivalency with existing barriers, we recommend that the design loads reflect the tested static capacity of the MNRO standard barriers i.e. if the tested transverse static capacity of the barrier is 40 kN, the **factored** transverse design load be specified as 40 kN. This would help ensure the development of barriers with similar static strengths to the MNRO standard bridge barriers.

Should the MNRO adopt this rational approach, they should recognise that a structural analysis would not always accurately predict the capacity of a bridge barrier. As an example, the tested transverse static capacity of the typical side mounted timber curb is 38 kN. A structural evaluation of this curb by Sargent and Associates Engineering Ltd (*MFR Standard HSS Bridge Guardrail for Concrete Slab Girder Bridges Structural Concept Review, September 20, 2007*) predicted a transverse capacity of 2 kN. A similar evaluation by the University of British Columbia as part of the recently completed barrier testing program predicted the transverse capacity of the same barrier to be between 0.2 kN and 62.5 kN.

Given the difficulty in predicting the capacity of a bridge barrier, we recommend the MNRO require static testing of the proposed barrier to verify the analytically predicted capacities. This is similar to the approach adopted by AASHTO LRFD that specifies a design load to facilitate the development of the bridge barrier and then requires crash testing in accordance with MASH to verify its performance.

Static testing of timber bridge barrier (courtesy of UBC, 2010)

Where the MNRO requires a higher level of performance, we recommend the adoption of standard crash tested barriers. We recommend that the MNRO review previously tested TL-1 curbs and TL-2 barriers, modify them to suit MNRO requirements and develop standard barrier details. Should the MNRO allow the development of alternative TL-1 and TL-2 bridge barriers, we recommend the adoption of the AASHTO LRFD design loads.

Table 3-1 lists suggested design loads for consideration by the MNRO for the three categories discussed in Section 2.

Table 3-1
Summary of Suggested Factored Barrier Design Forces

Factored Design Forces	Category		
	I[1,4]	II[2,4]	III[3,4]
Transverse Load, kN	40	60	120
Longitudinal Load, kN	20	20	40
Vertical Load, kN	20	20	20

Note:
1. Minimum capacity of MNRO standard bridge barriers based on UBC static tests. The magnitude of these forces needs to be confirmed through further study.
2. AASHTO LRFD specified design forces for TL-1 barrier.
3. AASHTO LRFD specified design forces for TL-2 barrier.
4. As discussed in Phase 1 of our Study, further investigation may allow for the reduction of these loads by 40% to account for dynamic amplification effects.

In addition to considering the strength of the barrier, the MNRO should also require:

.1 The proposed barrier's roadway face provides a smooth continuous alignment.
.2 Barriers meet specific height requirements recognising that on single lane bridges, some overloads extend over the deck edge and hence, increased height might result in damage to the barrier. The current height of the MNRO standard barriers is 500 mm while the US Forest Service requires curbs to be a minimum 460 (18") high. We recommend that barrier height be limited to 500-600 mm for single lane bridges using MNRO standard bridge barriers. Where the MNRO requires TL-1 or TL-2 barriers, the bridge width should account for the tracking of extra-wide loads to minimize the possibility of loads extending over the bridge barrier.
.3 Bridge delineators should not present a hazard to errant vehicles.

3.1 Crash-Testing Versus Static Testing

In developing these recommendations, we have suggested that the MNRO develop standard barrier details based on crash tested barriers as prescribed by CHBDC and AASHTO LRFD to ensure that the prescribed minimum level of containment is provided. However, if the MNRO continues to allow the development of alternative barriers, we have recommended the use of static testing to verify the structural capacity of a barrier. This recognises that static testing is inexpensive when compared to crash testing, and test results have shown that static load testing of barrier anchorages provides maximum load values very close to those obtained from full-scale tests. However, the MNRO should recognise that static testing is not sufficient to determine the crash test performance of a barrier, which evaluates the following performance aspects of the complete barrier system:

- Containment level - the barrier's ability to keep the impact vehicle from leaving the travel surface.
- Occupant risk - whether detached barrier elements are likely to enter occupant compartment.
- Post-impact vehicular trajectory - the potential of the impact vehicle to result in a secondary collision, or overturn as a result of the initial impact.

Barrier performance in the above areas can only be determined by full-scale crash testing and as such, static testing alone will not completely determine barrier performance. Recognising that sufficient funds are not available to crash test the current MNRO standard bridge barriers, the MNRO should complete a field evaluation of the barriers and their performance during vehicular impact to confirm that they provide an acceptable level of containment. Inspection criteria should include visible damage to the barrier systems and their deck connections. Where possible, the MNRO should also review accident reports to investigate level of containment, post-impact vehicle trajectory, and the extent and type of injuries sustained by vehicle occupants. A review of this information will allow the MNRO to establish whether the current standard barriers provide an acceptable level of containment.

3.2 Upgrading Existing Bridge Barriers

Evaluation of the bridge barriers installed on the existing bridge inventory using the proposed new barrier selection criteria will indicate circumstances under which that a number of bridge barriers should be upgraded. As a result, we recommend the MNRO develop guidelines to help determine when barrier upgrading is appropriate. These guidelines would account for:

- If the bridge barrier is performing adequately and the level of containment provided is appropriate, the barrier need not be upgraded.
- If the safety hazard is higher than normal, the bridge barrier should be scheduled for replacement with a barrier that provides higher containment.
- If the safety hazard is higher than normal and the bridge barrier is already scheduled for replacement as part of ongoing bridge maintenance, a barrier that provides higher containment should be installed.
- If the hazard to pedestrian traffic is higher than normal, the installation of pedestrian facilities, such as a walkway or refuges, should be considered.

4 Summary of Proposed Barrier Selection and Design Philosophy

We propose that the MNRO develop a bridge barrier selection and design methodology that:

- Is appropriate for the low traffic volumes and trained drivers that typically utilize the bridges.
- Addresses the potential for public use.
- Accounts for hazards.
- Considers the installation of approach barriers.
- Allows for the use of static testing and field evaluation in lieu of crash testing.

We have proposed the MNRO categorize bridges based on an assessment of various risk factors. For each category, the MNRO will define minimum barrier requirements. Given the satisfactory historical performance of the existing standard barriers, we recommend that the MNRO continue to use them on bridges where normal levels of containment are required. Where increased containment is appropriate, we recommend that the MNRO adopt either TL-1 or TL-2 performance level barriers.

We recommend that the MNRO mandate the use of standard barriers and limit the ability of owners or engineers to develop alternative barrier systems. Where alternative barriers systems are proposed, we recommend the static testing of the proposed barrier to verify the predicted capacity is equivalent to the mandated barrier.

5 Closure

This report was prepared for Ministry of Forests, Lands and Natural Resource Operations in conclusion of the scoping study and to establish the technical design criteria to be adopted by detail engineering an defines a specific scope of work to be undertaken during detailed design engineering encompassing the preparation of design drawings and technical specifications.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

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Appendix A - Sample Warrant for Bridge Barrier Selection (US Forest Service)

ROAD NUMBER - MILEPOST

BRIDGE NAME

Proposed structure length	xx m	Height above channel	xx m
Traffic Service Level	D	Road Maintenance Level – Operating	2
Bridge meets NBIS Standards	Yes/No	Road Maintenance Level – Objective	2

From FSH 7709.56b Transportation Structures Handbook:
7.24-5. Exceptions to using bridge railings. Consider omitting railing and installing a curb-only system for bridges at low hazard sites that experience low-volumes of low-speed traffic, and when object markers can provide sufficient advance warning of the bridge. Base the decision to install a protective railing system on an analysis that evaluates the specific site conditions, such as the amount, type, and speed of traffic, and the hazards involved.

Consider omitting the bridge railing under the following conditions:

a. The road is used at low speeds by drivers generally familiar with the road.
   - *Describe traffic speed and type of users. For example: Traffic is primarily low speed. The majority is administrative, logging, or logging associated or residents of nearby communities.*

b. The road is not heavily used.
   - *Describe traffic patterns. For example: Traffic is light. It is not a thru road, and does not provide access to any special recreation attractors. Primary recreation use is hunting and firewood gathering.*

c. The bridge is relatively short and located on a tangent.
   - *Describe bridge and approach geometry. For example: Expected length is approximately xx meters. It is located on a tangent, no curve widening is necessary.*

d. The bridge width is equal to the traveled way plus shoulders.
   - *Yes or no, the bridge width provides for the traveled way plus required curve widening.*

e. Separation is provided for vehicles and sidewalk pedestrians.
   - *Describe pedestrian accommodations, if needed. For example: There will not be a sidewalk. Pedestrian use will be almost non-existent.*

f. Hazards created by the un-railed bridge are not unusual in comparison to the exposure presented by the rest of the road.
   - *Describe road hazards along the rest of the road, such as side slopes, distance downhill to a slope break, etc. For example: A 380 mm (15-inch) high curb would result in a bridge hazard similar to hazards associated with driving the remainder of the road. Estimated height of the roadway above the channel is less than 3 meters. Approach fill slopes will be approximately 1.25 to 1. Typical fill slopes on forest roads are 1.25 to 1 and often higher than 3 meters.*

g. Curbs are provided for loadings that conform to AASHTO specifications.
   - *Yes or no, design is in accordance with AASHTO.*

h. Object markers outline the bridge and mark the curbs. Place object markers in accordance with Forest Service Guide for Traffic Control Devices and the Manual of Uniform Traffic Control Devices.
   - *Describe object markers. For example: Object markers will be installed as part of the bridge construction contract in accordance with Forest Service and AASHTO requirements.*

Based on these conditions, it is my decision to not require bridge and approach guardrail.

Forest Engineer, ___________National Forest

Date