R E P O R T

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BRITISH COLUMBIA
Ministry of
Forests, Lands and
Natural Resource Operations

Phase III
Guideline for Barrier Selection and Design

Associated Engineering

CANADA'S 50 BEST MANAGED COMPANIES

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Date........ 05-Aug-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 barrier design. As a result, the **Ministry of Forests, Lands and Natural Resource Operations** (the Ministry) retained **Associated Engineering** (AE) 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. In Phase 2, we presented a proposed *Barrier Selection and Design Philosophy*, which we based on the previously completed literature review and current Ministry practices. In this phase, Phase 3, we present a proposed *Guideline for Barrier Selection and Design*, based upon the philosophy proposed in our Phase 2 Report.

The work completed to date suggests that barrier selection and design comprises:

- Defining the level of containment required based on site-specific characteristics including traffic type (mix), traffic volume and speed, bridge width, road curvature and height of the bridge above ground/water.
- Selecting or designing an appropriate bridge barrier that will provide the desired level of containment.

The following sections present a proposed methodology to facilitate the decision making and selection/design processes.

2 Barrier Selection

To facilitate the selection of an appropriate barrier that provides sufficient containment, we recommend the development of a decision flowchart to determine to the required level of containment. We have included a draft decision flowchart based on discussions with the Ministry in **Appendix A**. The decision flowchart incorporates the following bridge and traffic characteristics:

- To account for traffic mix and volume, and the associated level of containment, we propose the following classifications:
  - **Type 1:** The road is travelled exclusively by industrial vehicles operated by drivers familiar with driving conditions and safety protocols of the route.

  - **Type 2:** The road is predominantly travelled by industrial vehicles operated by drivers familiar with driving conditions and safety protocols of the route, with less than X[1] Vehicles per Day (VPD).
  - **Type 3:** Although designated an industrial road, a significant portion of the traffic constitutes uncontrolled public traffic operated by people who may be unfamiliar with the driving conditions and safety protocols of the route, with less than Y[1] VPD.
  - **Type 4:** The road is travelled primarily by uncontrolled public traffic mixed with industrial vehicles, and sees traffic volumes exceeding Y[1] VPD.
- To account for the height of the bridge above water we assumed that bridges with deck elevations more than 5.0 m above present water require a higher level of containment. This is consistent with the approach adopted by the BC MoTI and Ontario Ministry of Natural Resource Operations.
- To account for vehicle operating speeds, we assumed that bridges require a higher level of containment where the design speed exceeds set thresholds of 50 km/hr and 80 km/hr.
- To account for the increased angle of impact and possible increased road curvature associated with wider bridges, we assumed that a higher level of containment is required on bridges with deck widths that exceed set thresholds of 5.6 m and 8.0 m.

Using these criteria, we recommended that the Ministry define the following three containment levels:

Containment Level 1 (CL-1): This level of containment is suitable on bridges that display the flowing characteristics:

- Exclusively industrial traffic and minimal public traffic
- Relatively low height above water/hazard.
- Good vertical and horizontal alignment.
- No pedestrian traffic.
- Normal operating speeds

Containment Level 2 (CL-2): This level of containment is suitable for bridges that display one or more of the following characteristics:

- Limited use by the public and pedestrians – users who 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.

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[1] The Ministry to develop traffic volumes “X” and “Y”.

Containment Level 3 (CL-3): This level of containment is suitable for bridges that display on or more of the following characteristics:

- 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.

3 Barrier Design

To ensure the provision of the minimum specified level of containment described in the previous section, we recommend that the Ministry mandate the use of pre-approved standard bridge barriers. Based on the proposed three levels of containment, we recommend that the Ministry adopt the following:

Containment Level 1: Adopt the current standard bridge barriers including the top and side mounted timber barriers and the side mounted HSS and W-Beam barriers. We recommend that the FLRNO maintain the current bridge barrier height of 500 mm.

Containment Level 2: Develop standard bridge barriers by modifying existing bridge barriers crash-tested to AASHTO MASH Test Level 1 (TL-1). We recommend that the Ministry adopt a minimum barrier height of 500 mm. Although lower than the 685 mm minimum height recommended by AASHTO LRFD 2010, this is similar to requirements mandated by the US Forest Service.

Containment Level 3: Develop standard bridge barriers by modifying existing bridge barriers crash-tested to AASHTO MASH Test Level 2 (TL-2).

Should the Ministry allow the development of alternative bridge barriers (i.e. bridge barriers not pre-approved by the Ministry), we recommend that the Ministry adopt the following design and testing methodology:

- Require the static testing of barriers to verify the analytical predicted capacities and confirm that the load deformation behaviour is equivalent to the existing barriers. To allow for comparisons to be made with existing Ministry standard bridge barriers, we recommend that the static testing be completed using the methodology outlined in the "*Experimental Evaluation of Concrete Decks with Guard Rail Systems*" by Villiard, Dickof, Angers, Scheider, and Stiemer, April 2011.
- Require the static design of bridge barriers for the forces listed in **Table 3-1**. The standard

CL-1 timber curb has a static capacity ranging from 20 – 30 kN, while the CL-2 HSS steel barrier has a capacity of approximately 60 kN. The 40 kN transverse load, FT, for CL-1, is intended to be an interpolation of the two levels of test results.

Table 3-1
Proposed Barrier Design Criteria

Factored Design Forces	Containment Level		
	CL-1[1,4]	CL-2[2,4]	CL-3[3,4]
Transverse Load, F_T, kN	40	60	120
Longitudinal Load, F_L, kN	20	20	40
Vertical Load, F_V, kN	20	20	20
Deflection, mm[5]	350	130	100
Load Application Height, mm[6]	500	500	510
Minimum Barrier Height[6]	500	500	685

Note:
1. Minimum capacity of MNRO standard bridge barriers based on UBC testing documented in “Experimental Evaluation of Concrete Decks with Guard Rail Systems”, April 2011. *The Ministry needs to confirm the magnitude of these forces 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.
5. Based on load cylinder stroke in 2011 UBC static testing.
6. Height measured from travel surface, as shown in **Figure 3-1**.

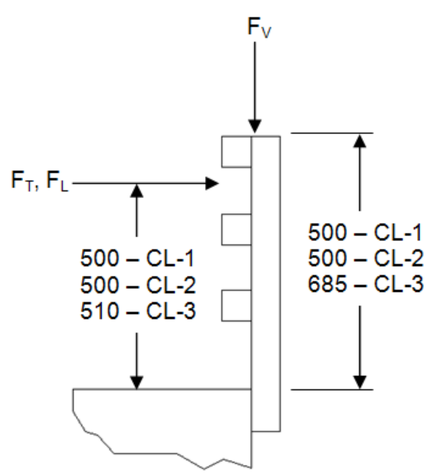

Figure 3-1
Minimum Bridge Barrier Height and Load Application Height

3.1 Pedestrian Railing

Where the Ministry expects significant pedestrian usage, we recommend the modification of the standard bridge barriers to include additional rails to achieve a minimum top-of-railing height of 1070 mm, the Code mandated minimum height for pedestrian railings. Notwithstanding, the Ministry should consider the effect that the higher rails may have on the ability of wide loads to cross the structure without damaging the pedestrian railing.

4 Approach Barrier Selection

Anecdotal evidence suggests that the majority of railing collisions on resource road bridges occur because the vehicle lost control on the bridge approach rather than on the bridge deck. The primary purpose of approach barriers is to direct errant vehicles onto the bridge deck, preventing them from encountering hazards outside of the roadway.

We recommend that the Ministry develop guidelines for determining whether approach barriers are required. These guidelines should prescribe a minimum approach barrier length based on a set of criteria, which could be selected from a flowchart, similar to that developed for selecting bridge barriers. We recommend that the flowchart account for approach curvature and embankment height. A suggested flowchart for approach barrier selection is presented in Figure 4-1 below.

Adequate connection between the approach barriers and bridge barriers is critical redirecting an errant vehicle onto the bridge deck. As such, we recommend that the Ministry develop standard approach barrier connections for each of its standard bridge barriers.

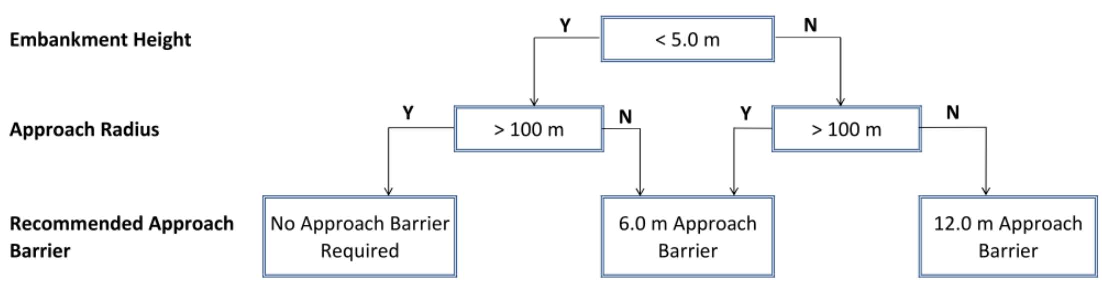

Figure 4-1
Approach Barrier Decision Flowchart

5 Further Work

This report presents a proposed *Guideline for Barrier Selection and Design*, based upon the philosophy proposed in our Phase 2 Report. We recognize that following the completion of this phase, the Ministry will need to take further steps to develop this guideline such that it can be incorporated into the Ministry's bridge design requirements.

We anticipate these required steps to include the following:

- Define limiting traffic volumes for use in the barrier selection flowchart.
- Develop factored forces for the static design of bridge barriers in consultation with UBC researchers.
- Create standard barrier designs for each containment level. We envisage that the Ministry will base these standard barrier designs on existing barriers, crash-tested to NCHRP Report 350 or MASH standards, and modify them to suit standard fabrication and installation procedures for industrial forest road bridges.
- Develop guidelines for the design of approach barriers for use on industrial roads.

6 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 and 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 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

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Appendix A - Sample Bridge Barrier Decision Flowchart

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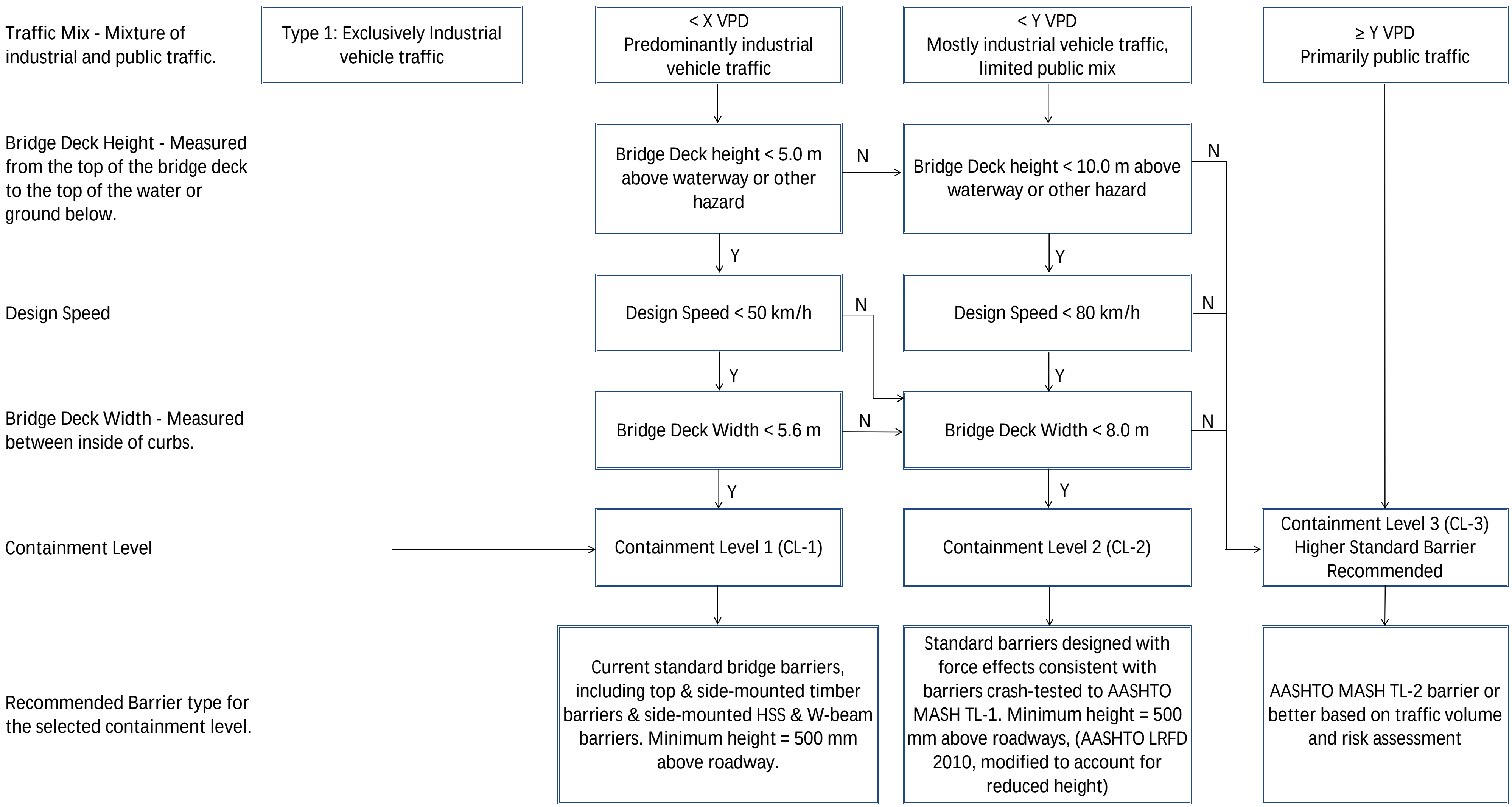
Bridge Barrier Decision Flowchart



Notes: 1.) The Ministry to develop traffic volumes X and Y.
2.) Where pedestrian use is expected, consider installing barrier-top rails to achieve a total height of 1070 mm.
3.) Where vertical grade exceeds the area-specific average (eg. > 4%), apply engineering judgement to determine whether a higher standard barrier is appropriate.