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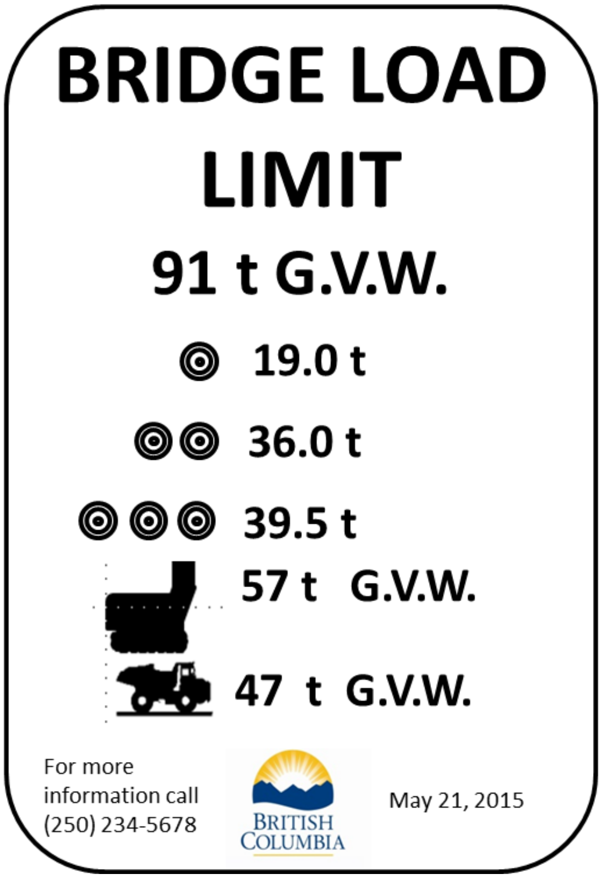

Forest Bridge Capacity Signage

A technical review and operational discussion of the FLNRO Engineering Branch ‘road load rating’ concept

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by:

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EXECUTIVE SUMMARY

Overloading of forest bridges is a source of concern to the B.C. Ministry of Forests, Lands and Natural Resource Operations (FLNRO) because of the unacceptable increase in risk to human safety and environmental integrity; and of reduced design service life and maintenance costs. Bridge capacity signage for forest bridges has become outdated and needs to be changed to reflect variability in current truck populations. Non-forestry sectors are increasingly utilising forest service roads (FSRs) and these industries employ a wide range of vehicle configurations that, when loaded for off-highway travel, may exceed forest bridge design limits. The FLNRO is taking steps to rectify this situation—one step is to inform all holders of road use permits on FSRs about the capacities of FSR bridges and, thereby, address overloading issues caused by a lack of knowledge or understanding about the FSR infrastructure. Another step is to develop an informative sign, to be posted at FSR road entry points, advising on bridge load limitations.

Buckland & Taylor Ltd. and SNT Engineering Ltd. were commissioned to determine the load limits of current and new (BCL-625, LOH and HOH) forest bridge designs in terms of tractor trailer GVWs and their axle group weights, and in terms of short (straight) truck and tracked equipment GVWs. A variety of existing bridge capacity sign formats were considered and new formats proposed. The question remained - how best to inform road users about the load limits? Rather than posting each individual bridge's capacity, a road load rating concept was proposed by which a single, minimum, bridge capacity is posted for each FSR network (and only bridges that have been down-rated would be individually posted).

In 2013, FPInnovations was contracted to review the short truck and tracked equipment load limits, and the assumptions that went into the calculation of all of the load limits; consider and recommend bridge capacity sign formats that would be both understandable and easily read; and gather feedback from its member forest companies and other stakeholders as to operational concerns that might arise with the implementation of a road load system.

This report presents the results of a technical check of the load limits proposed by Buckland & Taylor and by SNT Engineering, and includes a discussion of live load factors and other assumptions that went into the calculation of these load limits. Potential issues that might arise from the adoption of the various load limits are highlighted. Specific recommendations are made that could improve the accuracy of the load limit analysis and resolve some of the identified issues. A brief discussion about communicating the new load limits is included.

Options for bridge capacity sign formats are summarized and two formats recommended for use with the various bridge designs. A cross-section of stakeholders were contacted and solicited for feedback on the road load concept. Feedback generally supported the concept; however, some potential issues were identified. In some cases, potential solutions to the issues are also discussed. Finally, changes to Road Use Permits are recommended that would detail road load limits.

INTRODUCTION

The B.C. Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) has responsibility for bridge and major culvert designs and inspections on Forest Service Roads (FSRs). Bridge overloading is a source of concern because of the unacceptable increase in risk to human safety and environmental integrity; and of reduced design service life and maintenance costs.

FSR bridge capacity signs were originally based on 5-axle tractor pole trailers and there was a relatively narrow range of vehicle configurations used on forest roads. Licensees and their contract truckers understood and generally adhered to the terms and conditions of the road use permit. Further, the bridge design vehicles resembled the truck population. The Ministry of Forests (MoF) L-Series bridge design vehicles are defined in Anonymous (1999). Signage based on these 5-axle truck configurations is now outdated and needs to be changed to reflect current truck populations (McClelland, 2012). Currently, the forest industry employs a wide variety of tractor-trailer configurations to haul short log and tree length timber (e.g., 6-, 7-, and 8-axle combinations). As well, it is common practice for tracked vehicles (e.g., yarders, loaders and excavators) to be walked across bridges when making short moves in industrial locations.

Non-forestry sectors (e.g., oil & gas, mining, independent power projects) are increasingly utilising FSRs, however, and these road users may not understand or adhere to the terms and conditions of the road use permit or even know there is one. These industries employ a wide range of vehicle configurations that, when loaded for off-highway travel, may exceed forest bridge design limits. The FLNRO is taking steps to rectify this situation—one step is to inform all FSR users about the capacities of FSR bridges and, thereby, address overloading issues caused by a lack of knowledge or understanding about the FSR infrastructure.

Where FSR bridge capacity has been signed it has usually been with a single GVW load limit. The GVW load limit applies to many but not all vehicles—notably not to short trucks and tracked machines because their axle weights tend to be concentrated in a few axles and this generates force effects in excess of the design vehicle. The lack of understanding of concentrated loads may have contributed to some isolated bridge failures in which road users misunderstood what kind of loads the bridge could carry and, thereby, over-estimated the actual bridge capacity (Anonymous, 2009). Improved forest bridge load limit signage is needed to address all types of heavy vehicles likely to use FSR infrastructure now and in the future (McClelland, 2012).

In the early 2000s, the ministry commissioned a study to determine whether the MoF L-Series bridge design vehicles were "*reasonably representative of B.C. log hauling truck loadings and if these configurations were appropriate for use with the load factors in CHBDC [Anonymous 2000]. The findings indicated that for the current populations of trucks transiting forestry bridges the existing MoF L-Series design vehicles produced variable levels of design safety depending on the bridge span…It was recommended that the existing MoF L-Series design vehicles be modified for use with the design provisions of CHBDC*" (Gagnon, 2004). Gagnon (2004) presented three new design vehicles for use in the design of B.C. forest bridges:

- BCL-625 – for use with on-highway (legally loaded) log hauling trucks with GVW up to 63.5 tonnes.

- Light Off-Highway (LOH) – for use with all off-highway log hauling trucks with GVW up to 73.4 tonnes.

- Heavy Off-Highway (HOH) – for use with all off-highway log hauling trucks with GVW up to 114.2 tonnes.

The ministry contracted Buckland & Taylor Ltd. and SNT Engineering Ltd. to determine the load limits of the current L-Series and new (BCL-625, LOH and HOH) forest bridge design vehicles in terms of tractor trailer GVW and axle group weights (Gagnon, 2012), and in terms of short truck and tracked equipment GVWs (McClelland, 2013). The next question was how best to express the various load limits. The road load rating initiative was to evaluate the feasibility of posting a sign at a road entry point based on design vehicle configuration, as it would be impracticable and unworkable to sign each bridge, and to consider different sign formats. Individual bridge signage would only occur for bridges with sub-standard load ratings. It is noted that MoTI, typically, only posts bridges with sub-standard ratings.

In 2013, FPInnovations was contracted to review the short truck and tracked equipment load limits, and the assumptions that went into the calculation of all of the load limits; consider and recommend bridge capacity sign formats that would be both understandable and easily read; and gather feedback from its member forest companies as to operational concerns that might arise with the implementation of a road load system.

OBJECTIVES

The objectives of this project were to conduct a technical review of the engineering method and calculated load limits for all FSR bridge design vehicles; consider and recommend bridge capacity sign formats and capacity information for road use permits that would be both understandable and easily read; and to gather industry feedback about options for informing road users about FSR bridge capacities.

METHODOLOGY

In order to meet the objectives of the project, FPInnovations conducted the following tasks:

a) FPInnovations reviewed applicable bridge design documents and analyses, and discussed the load road rating concept with forest bridge designers.

b) FPInnovations calculated the factored live load force effects (shear and bending moment) generated by each B.C. forest bridge design vehicle over a range of typical forest bridge clear spans (3 to 36 m). The load limit of forest bridges designed for each design rating was assumed to equal the minimum force effect value calculated for any of the clear spans evaluated. The GVW and axle load limits for each bridge design rating was calculated using the methodology reported in Gagnon (2012) and was based upon a large data set of actual B.C. log hauling truck weights. These load limits were reported in Table 2 of McClelland (2013).

   Per the statistical analysis of B.C. off-highway log truck loading detailed in Gagnon (2012), L-Series tandem axle load limits were assumed to be 37% of the GVW load limit, the single axle load limit equal to 53% of the tandem axle load limit, and the tridem axle load limit equal to 110% of the tandem axle limit. The LOH and HOH tandem axle load limits were assumed to be 45% of the GVW load limit, the single axle load limit equal to 53% of the tandem axle load limit, and the tridem axle load limit of the LOH equal to 110% of its tandem axle limit.

   The live load adjustment factors for each analysis were set as appropriate for log hauling trucks with relatively tightly controlled payloads and crossing two girder forestry-type bridges. Referring to Section 14 of CAN/CSA-S6-06 log haul traffic was represented as Annual Permit (PA) traffic, with a live load factor of 1.60 corresponding to a reliability index (ß) of 3.75 for the design of simplified structures. Details about the live load adjustment factors used for this analysis are presented in Appendix 1.

c) There was no population data to support an analysis of heavy short trucks or tracked vehicles. Therefore, conservative loading arrangements were assumed for the analysis: the short truck was represented with the CAN/CSA-S6-06 CL-3 "*short truck*" design vehicle format and the tracked vehicle with a 4 m-long tracked piece of equipment (McClelland, 2013). The short truck and tracked vehicle loadings were increased until their force effects just equalled the minimum force effect (bending moment or shear) generated by each of the log hauling design vehicles above for the range of span lengths considered.

   Lacking data, the live load adjustment factors for the short trucks (live load factor, dynamic load allowance, load distribution factor) were assumed to be the same as used in the log hauling bridge design trucks analysis above.

   Lacking data, the live load factors for the tracked vehicle were also estimated based on the designer's judgement. Considerable discussion about the assumptions used in the McClelland (2013) analysis took place with the result that live load factors and load limits were revised, and an evaluation of load limits for gravel-over-log-stringer bridges was also included. Because tracked vehicles walking across bridges is an uncommon event and these vehicles tend to have a consistent, well-controlled loading, it was judged that they can be described as Permit – Controlled (PC) traffic (referring to Section 14 of CAN/CSA-S6-06). The live load factor for design was taken to be 1.30. Two types of bridges were considered for this part of the evaluation - two girder forestry-type bridges (consistent with the other evaluations) and short gravel-over-log-stringer bridges (sometimes used in remote Coastal road locations). The distribution factor for a tracked vehicle was taken to be 0.55 on 2-girder bridges because of the limited eccentricity possible with the wide undercarriage. The distribution factor for both the design trucks and a tracked vehicle on a log stringer bridge were assumed to be the same (0.23) with wheel load being carried by only 2 stringers. Finally, the dynamic load allowance for the log stringer bridge case was reduced slightly from the 0.30 level used for the 2-girder bridge evaluation to reflect the slow travel speeds, short spans, and lack of (potentially) overloaded axle groups. The live load adjustment factors used for these evaluations are presented in Appendix 1.

d) The contents of Table 2 (McClelland, 2013) were reviewed in light of current truck configurations and issues arising from the proposed load limits were highlighted. FPInnovations recommended a methodology and proposed higher axle load limits for the BCL-625 design vehicle when used to represent forestry trucks.

e) A range of load rating sign formats were considered and sign formats were recommended that were judged to be easily read and understood, and that provided full information for the road user. FPInnovations recommended road use permit additions to supplement road load signage, and other measures to communicate the load rating changes to road users.

f) FPInnovations solicited feedback about the road load limit concept from the B.C. Forest Safety Council, FPInnovations' B.C. extension officers, the B.C.log hauling committee, the four largest B.C. forest companies (CANFOR, Tolko Forest Industries, Western Forest Products, West Fraser Mills), Shell Oil, a consultant for Aero Transport, B.C. forest bridge design companies (Associated Engineering (B.C.) Ltd., Stonecroft Project Engineering, AllNorth Engineering, Onsite Engineering Ltd., and Caliber Bridge and Design Ltd.) and FLNRO Coast regional engineering staff. Based on this feedback, FPInnovations made a recommendation about proceeding with implementation of a road load limit concept.

RESULTS AND DISCUSSION

Discussion of load factors used in analysis

Associated Engineering (B.C.) Ltd. (2002), in their evaluation of CAN/CSA-S6-00 as a design approach for forestry bridges, provided the details about bridge design life and reliability index (Table 1). Table 1 was updated with information from CAN/CSA-S6-06. Although the MOF Manual did not specifically estimate target reliability index, it was implied that the MOF Manual was trying to be consistent with CAN/CSA-S6-88 and so their annual and design life reliability indices are assumed to be the same.

Table 1: Design Life and Safety Reliability Index (Associated Engineering (B.C.) Ltd. 2002) updated with information from CAN/CSA-S6-06 and (Associated Engineering (B.C.) Ltd. 2012)

Code	Design Life	Target Reliability Index (ß)	
		Annual	Over the design life
CAN/CSA-S6-06	75 years	3.75	3.5
CAN/CSA-S6-00	75 years	3.75	3.5
CAN/CSA-S6-88	50 years	3.75	3.5[1]
MoF Forest Service Bridge Design and Construction Manual	45 years	3.75	3.5

The design life and annual reliability index (ß) are important design variables as they are used to define the following:

Load Factors

Using the design life and annual reliability index, the load factors and load combinations have been calibrated to a uniform level of reliability. At the Ultimate Limit State, use of the load factors included in S6-06 and S6-00 (Cl. 3.5.1) result in a probability of approximately 1% that the design load will be exceeded during the 75-year design life of the structure. The live load factors have been calibrated to reflect variability of truck traffic on public highways. Should the factors be applied to other live loads, such as the MoF L-Series design trucks, a different safety level will be attained.

Table 2 summarises the load factors associated with load effects and bridge design code. It must be noted that these factors cannot be viewed in isolation, as other parameters (dynamic load allowance, live load distribution) also directly affect the design.

"*Although the individual weights of the overall population of loaded highway trucks can vary widely, the mean weight of the loaded truck population is typically about 10% to 15% below the posted load limits. This represents the general level of adherence of the truck population to the posted load limits with typical load limit enforcement measure in place*" (Gagnon, 2012) (contained in McClelland, 2013). The values defined in S6-06 provide a prescribed uniform level of reliability based on an acceptable probability that the factored loads will be exceeded during a specific time period for typical highway bridges subject to the specified design loads.

[1] S6-88 was based on a 50 year β of 3.5. This is roughly equal to an annual β of 3.75 as well. The difference in going from an annual β to either a 50 year or 75 year β is small for most vehicle populations. *Darell Gagnon. Buckland & Taylor Ltd*.

Table 2: Load Factors associated with an annual reliability index of 3.75 (used in new designs)

Load Effect	Load Factor (S6-06)	Load Factor (S6-00)	Load Factor (S6-88)
Live load (α_L)	1.70	1.70	1.60
Dead Load (α_{D1}) – Manufactured components included precast concrete and steel girders (excluding wood)	1.1	1.1	1.2
Dead Load (α_{D2}) – Wearing surfaces, based on nominal or specified thicknesses	1.5	1.5	1.6

Using the CAN/CSA-S6-06 Section 14 provisions for reducing target reliability, Associated Engineering (2012) evaluated the force effects of 7- and 8-axle log hauling trucks on the basis of them being Normal Traffic (Alternative Loading) and being Permit Annual (PA) Traffic. Vehicles classified as Normal Traffic are assumed to have high GVW variability and are, therefore, assigned higher live load factors. Vehicles classified as PA Traffic typically have practices in place to control the weights of the vehicles and to limit the probability that the actual GVW will be greater than that assumed during the evaluation. Table 3 illustrates the range of load factors that were used in that evaluation.

Table 3: Load Factors associated with a target reliability index of 3.25 (used in load ratings)

Traffic Type	Span Length	Live load (α_L)	Dead Load (α_{D1})	Dead Load (α_{D2})
Normal	Short	2.10	1.08	1.16
	Other	1.56	1.08	1.16
Permit Annual	Short	1.59	1.08	1.16
	Other	1.42	1.08	1.16

Note: Per Clause 14.13.3.1 in Anonymous (2006), 'short spans' are ≤6m for evaluating shear but ≤10m for evaluating bending moment.

Bridge engineers using the above method to load rate existing forest bridges will estimate bridge capacities differing by 10%, depending on their definition of traffic using the bridge. It is recommended, therefore, that the FLNRO provide guidance on this matter in the case of FSR bridge evaluations so that a consistent approach is used in all load rating. Such an approach should consider the type of traffic anticipated to use the bridge during its design life and the effectiveness of enforcement efforts to control truck GVWs.

Earlier traffic studies have shown that the load variability for log hauling traffic is less than that of the general truck population. According to Gagnon (2012) this reduced variability of log hauling traffic supports the reduction of design live load factors of 1.70 (for HOH, LOH, and BCL-625 design vehicles) or 1.6 (for L-75 to L-165 MoF L-Series vehicles) to 1.50. Although no traffic data was available, Gagnon (2012) assumed that L-45 design live loads could also be reduced to 1.50. By the same logic, L-60 design live load, which was not considered by Gagnon (2012), might also be appropriate to reduce to 1.50. Gagnon used this logic to increase the HOH, LOH, and BCL-625 GVW load limits by 13.3% (1.7/ 1.5) and the MoF L-Series load limits by 6.7% (1.6/ 1.5).

McClelland (2013) noted that forest bridges have been designed over the years with a variety of Codes and methodologies; therefore, there is no one "official" live load factor that can be used for all structures. For example, the L-45 design vehicle was popular in the 1980s, L-60 was popular in the 1990s, and in the late 1990s to 2000s, BCL-625 (for highway legal vehicles) and the L-75 (for off-highway vehicles) became popular. For the purposes of the McClelland (2013) evaluation of short truck and tracked equipment maximum GVWs, the live load factors for all of the design truck configurations were set to 1.60 despite Buckland & Taylor's use of 1.5 for estimating max GVW and axle group limits. The approach in McClelland (2013) results in live load demands (Moment, Shear) from the bridge design vehicles being 6.7% smaller than specified by Gagnon (2012).

McClelland (2013) selected 1.6 when choosing a live load factor for the short truck because there was no population studies to justify a live load factor of 1.5. This decision also appears to be reasonable given the consistency of short truck (i.e., gravel/rock truck) loading and axle configurations. Unlike the analysis illustrated in Table 3, the CL-3 short truck used by SNT to model short truck performance has been calibrated to use live loads that don't require special attention to 'short spans'.

Recommendation: *that FLNRO conduct research on load variations of short truck vehicle GVWs.*

McClelland (2013) specified a conservative live load factor of 2.0 when evaluating the live load demands of tracked vehicles because of the lack of available GVW data and because the operator could change the left-right load distribution by rotating the cab. This decision resulted in maximum GVW that are less than the GVW of some common pieces of tracked equipment used in forest operations (e.g., a 38.2 t CAT 235 excavator exceeds the 35 t capacity of L-75 bridges; all of the heaviest grapple yarders (90 – 115 t) exceed the 85 t capacity estimated for L-165 bridges. This situation is of concern because it may cause some in industry to disregard the stated maximum GVWs on the basis that these bridges were considered sufficient to support these loads in the past.

Tracked equipment GVWs may be relatively consistent given that they carry no payload and manufacturers may be able to provide maximum operating weights (with guarding packages, wire rope, fuel, oil, etc.) After discussion with local forest bridge experts[2], a smaller live load factor was selected and the load limits re-evaluated. This resulted in higher estimates of bridge load limits for tracked vehicles. In addition, because gravel-over-log-stringer bridges sometimes are used in remote locations coinciding with where tracked equipment may be walked across bridges, an evaluation of load limits also was conducted with these types of bridges (i.e., slab type bridges and gravel-over-log-stringer bridges).

Dynamic Load Allowance and Live Load Distribution Factor

CAN/CSA S6-88 defines the dynamic load allowance (DLA) as a function of span length. S6-00 revised this definition, resulting in the DLA being a function of the axle configuration causing the load effect that is being evaluated. This helps to account for the impact of overloaded axle groups. One of the problems

[2] Teleconference discussion. Darrel Gagnon (Buckland & Taylor), Julien Henley (Associated Engineering), Brian Chow (FLNRO) and Gary McClelland (SNT Engineering). 19 August 2014.

with this definition is that the DLA varies with load effect, span length and location where the force effect is being considered. Given the complexity in choosing the appropriate DLA, Associated Engineering (2002) suggested that it be based on span length, similar to the requirements outlined in S6-88. Further, they recommended the following values be adopted:

- Span < 10 m, DLA = 30%
- Span ≥ 10 m, DLA = 25%
- Where only a single axle is used, the value of 40%, as required by S6-00, should be adopted. (Where using a tandem axle for deck design they recommended a value of 40% be applied to both axles.)

The Forest Service Bridge Design and Construction Manual (Anonymous 1999) requires that DLA equal 30% for all bridges.

Gagnon (2012) did not utilize DLA or distribution factor (DF) when stating the maximum GVW of the bridge design loadings and maximum axle group weights. This was done for simplicity and assumed that the same DLA and DF values would be used for the vehicle being compared.

McClelland (2013) made similar assumptions for the short trucks. In lieu of having actual data on DF, the DF for short trucks was taken to be the same as for the bridge design trucks. This assumption seems reasonable given that short trucks are likely to have some left-right payload imbalance and rock trucks are equipped with wide tires that would limit eccentric tracking. This value is less than assumed for the log hauling trucks which may be reasonable given the nature of the payload and the wider tires used for larger rock trucks. Again, because short trucks are similar to the bridge design vehicles and assumed to interact with a bridge in the same way, and no DLA data on them was available, McClelland (2013) assumed their DLA to be 0.30.

In lieu of having actual data on DF, McClelland (2013) assumed that the DF for tracked vehicles should be 0.55. This value assumed that the tracked equipment created very balanced loading of the bridge beams by staying aligned with the bridge centreline, not carrying payload, and not stopping to do work while on the bridge (e.g., rotating its cab). Provided these assumptions agree with actual practice the choice of 0.55 seems reasonable. Because a DF different from the design vehicle was assumed, to facilitate the comparison calculations a DF for the design vehicle was required. A value of 0.69 was used. This is the value for a typical 4.27 m wide bridge roadway supported by underlying twin girders at 3.0 m on-centre. Other configurations, such as log stringer or concrete slab bridges, have different values of DF. A value of 0.23 was estimated for use with log stringer and slab bridges.

The DLA for tracked vehicles also was selected in the absence of published data.[3] Given the slow travel speed, short spans and lack of individual axle groups it was judged to be appropriate to use some value less than 0.3. A DLA of 0.24 was assumed for the analysis.

[3] The very limited information that Buckland & Taylor has located in the past indicates that DLA for tracked vehicles is somewhat higher than typical highway vehicles. However, there was very little reliable data presented. *Darrel Gagnon. Buckland & Taylor Ltd.*

Recommendation: *FLNRO should improve confidence in this analysis by conducting a literature review or other research into the LLF, DF and DLA of tracked vehicles.*

Technical check of bridge load limit values

Short truck load limits

The maximum bending moment and shear was calculated for each bridge design loading for a range of simple span lengths (3 to 36 m in 3 m increments). This process was repeated for short trucks having the maximum GVW reported in McClelland (2013). McClelland (2013) calculated maximum shear force as occurring 1 m from the end of the simple span whereas this analysis estimated maximum shear at the end of the span. As a result, the calculated maximum shear forces differed by a small amount between the McClelland and the FPInnovations analyses but, being a relative force effects comparison, the same load limits were produced. Live load factors were not applied to either the design load or the short truck because the same three live load factors (LLF, DLA, DF) were used in all cases and so would cancel each other. Dead loads were not included in the calculation of relative force effects because it was assumed to be the same for both bridges and so the resulting force effects would cancel each other out. Table 4 presents the load limits calculated for each bridge design (McClelland, 2013).

McClelland (2013) also reported short truck load limits based on the sum of the single axle load limit plus the tandem axle load limit. For example, the short truck limit calculated for L-75 bridges was calculated to be 36 t, however, the sum of the single and tandem axle load limits was 41 t. Heavy off-highway rock truck axle loads may exceed the log hauling truck axle loadings used to estimate the single and tandem axle limits. Therefore, it would be prudent to estimate short truck load limits based on the present methodology (using the CL-3 short truck from CAN/CSA S6-06).

Table 4: Table of maximum load limits for B.C. forest bridge design vehicles (McClelland 2013)

Design Vehicle	**GVW Load Limit (tonnes) [a,c]**	**Single Axle Load Limit (tonnes) [b]**	**Tandem Axle Load Limit (tonnes) [b]**	**Tridem Axle Load Limit (tonnes) [b]**	**Short Truck Load Limit (tonnes) [a]**	**Tracked Equipment Load Limit (tonnes) [a]**
L-45	44	8.5	16.0	17.5	26	25
L-60	58	11.5	21.5	23.5	28	28
BCL-625	64	9.0	17.0	24.0	33	33
L-75	73	14.5	27.0	29.5	36	35
LOH	83	20.5	38.5	42.0	46	44
L-100	97	19.0	36.0	39.5	47	44
HOH	129	32.0	59.5	n.a.	71	67
L-150	145	28.5	53.5	n.a.	70	66
L-165	160	31.5	59.0	n.a.	90	85

Notes:

a. *GVW load limits have been rounded to the nearest tonne.*

b. *Axle group load limits rounded to the nearest ½ tonne.*

c. *GVW load limits of the L-Series design trucks have been increased to reflect the reduced variability in loading expected with log hauling trucks.*

In all cases and for each span considered, the force effects calculated for the short truck with the load limit specified in Table 4 did not exceed the force effects from the design vehicle. Figures 1 and 2 illustrate the calculated force effects over a range of spans for the short truck versus the L-75 design load. In the case of the L-75 bridge design the short truck with a 35.8 t GVW was close to exceeding both the shear and moment of the bridge design vehicle. When the short truck was increased by 0.5 t its shear and bending moment exceeded that of the L-75 design vehicle. All of the McClelland (2013) short truck load limits given in Table 4 were found to be accurately estimated; and, when the short truck GVW was increased by 0.5 to 1.0 t the design vehicle force effects (shear or bending moment) were exceeded in every case.

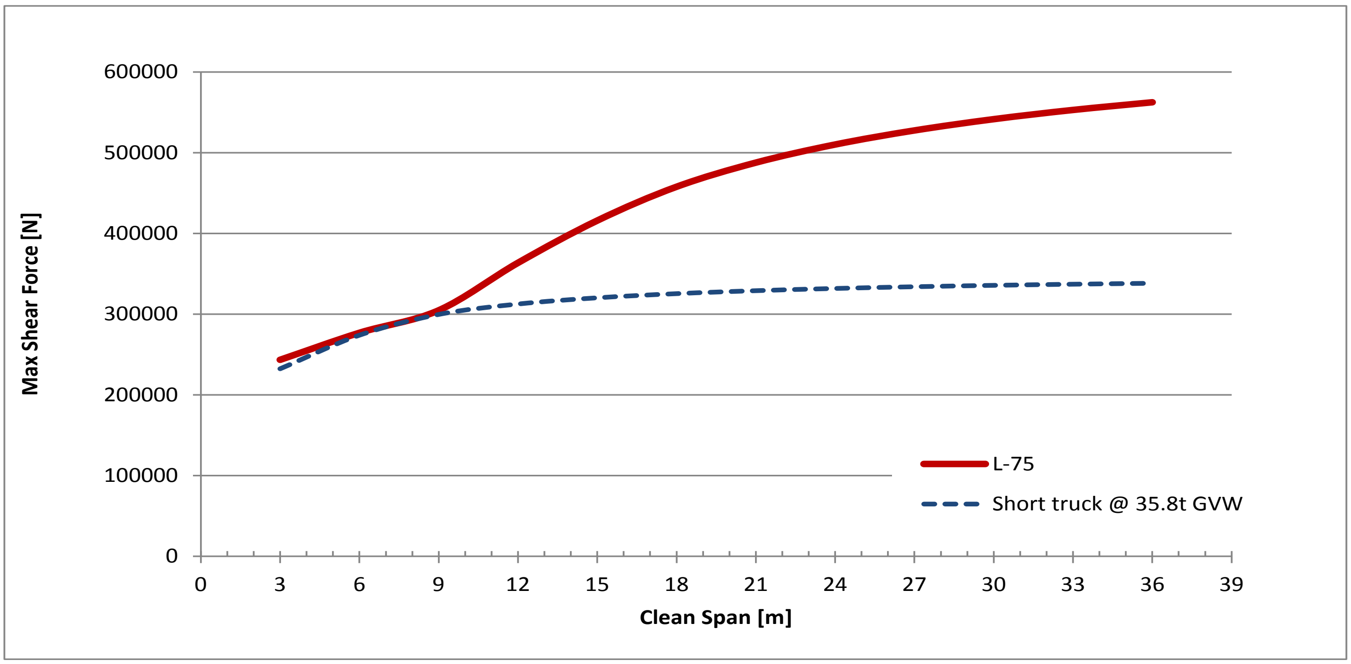

Figure 1: Max shear force comparison for simple span forest bridges. Unfactored L-75 design load vs. short truck at specified load limit.

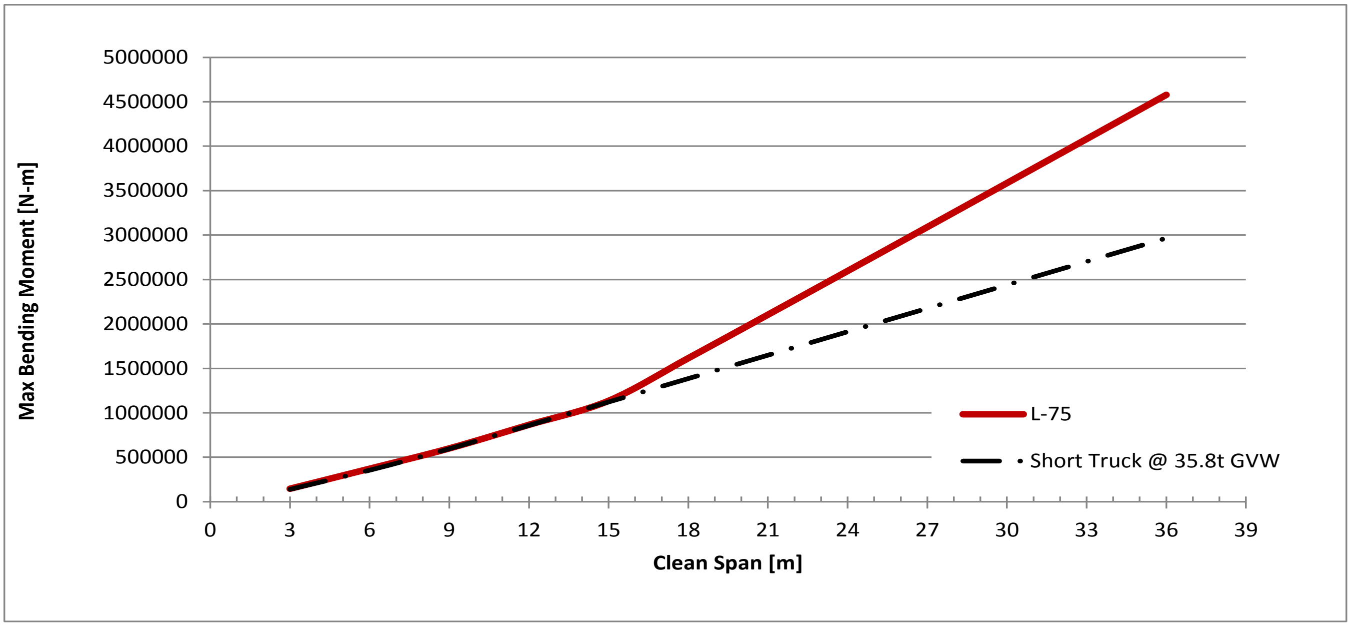

Figure 2: Max bending moment comparison for simple span forest bridges. Unfactored L-75 design load vs. short truck at specified load limit.

Tracked equipment load limits

The maximum bending moment and shear was calculated for tracked equipment with a 4 m-long contact track length and maximum GVW as specified in Table 4. A brief review of track lengths revealed that track contact lengths of common forestry vehicles ranged between 3.2 m and 5 m so the choice of a 4 m-long contract track length appears reasonable. As with the short truck, the force effects were compared with that from the bridge design vehicles, for span lengths from 3 to 36 m. McClelland (2013) calculated maximum shear force as occurring 1 m from the end of the simple span whereas this analysis estimated maximum shear at the end of the span. As a result, the calculated maximum shear forces differed by a small amount between the McClelland and the FPInnovations analyses but, being a relative force effects comparison, the same load limits were produced. As with the short truck analyses, dead loads were not considered in the comparison of relative live load force effects.

The tracked equipment load limits were re-calculated for typical 2-girder forest bridges using a lower live load factor than used in McClelland (2013) (i.e., 1.30 vs 2.0). This increased load limits by approximately 54% over those in McClelland (2013). Tracked equipment load limits also were calculated for slab type and gravel-over-log-stringer forest bridges using the same live load factor, but lower DLA and distribution factors (see Appendix 1). Figures 3 and 4 illustrate the calculated force effects of the tracked equipment versus the L-75 design load for a range of simple spans. As can be seen, the tracked equipment load limit was governed by its bending moment rather than its shear.

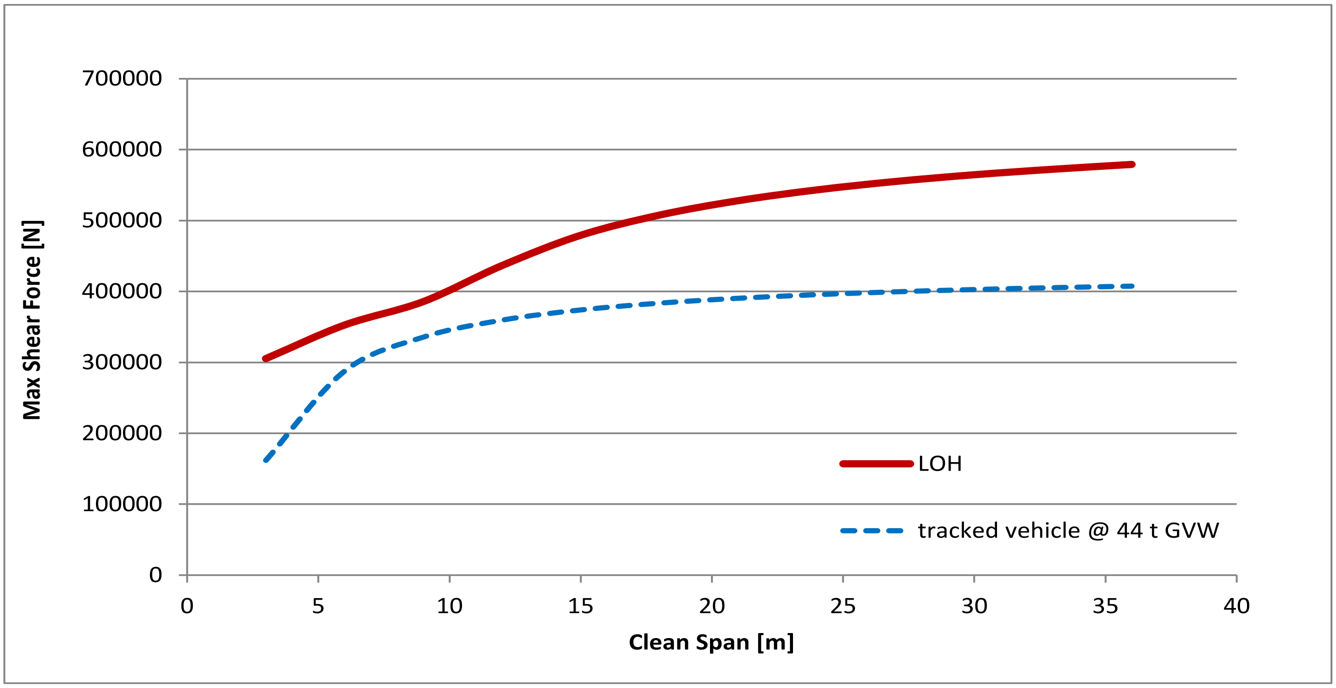

Figure 3: Max shear force comparison for 2-girder simple span forest bridges. Unfactored LOH design load vs. tracked equipment at specified load limit.

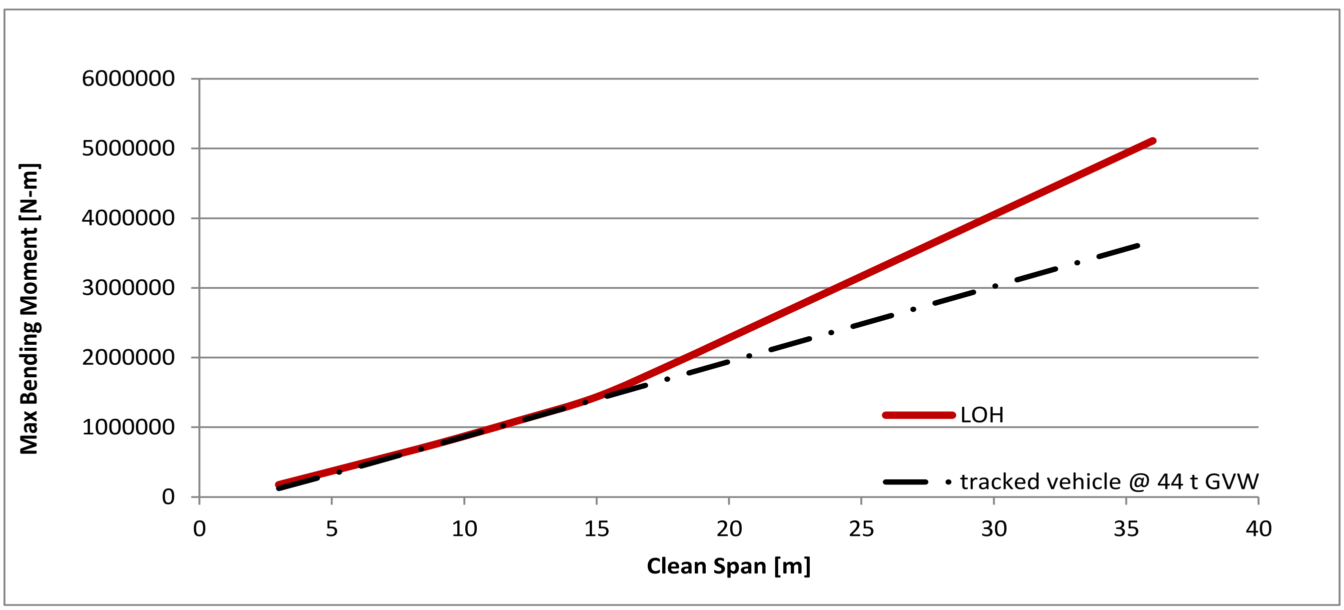

Figure 4: Max bending moment comparison for 2-girder simple span forest bridges. Unfactored LOH design load vs. tracked equipment at specified load limit.

As previously discussed, the load limits for tracked vehicles calculated in McClelland (2013) are anticipated to be a concern because in the past these bridges were considered sufficient to support the heaviest class of yarders (90 to 115 t GVW). However, after discussion with local forest bridge experts lower live load allowance factors were found to be justified and these resulted in a load limit in excess of the piece of heaviest tracked equipment. The calculation of load limits for slab type and gravel-over-log-stringer bridges found design load limits that were approximately 19% less than the corresponding 2-girder forest bridges. The heaviest design load limit was 109 tonnes for L-165 bridges. New slab or gravel-over-log-stringer bridges will need to be built with heavier capacity than L-165 in order to carry the heaviest grapple yarders. Existing bridges can be individually load rated and this may produce sufficient load limits for L-165 bridges.

Recommendation: that the lower of the two tracked vehicle load limits (for slab and log stringer bridges) be used for posting design bridge limits, in general. Bridge designers should be informed about the higher load limits that apply to typical 2-girder forestry bridges so that these could be used on networks with no concrete slab or log stringer bridges, or existing log stringer bridges can be individually load rated. In addition, given the importance to industry and the Ministry, further investigation into the load limits for concrete slab bridges and into the DLA for log stringer bridges should be undertaken.

MoF L-Series design vehicle GVW and axle group load limits

Based on population studies conducted by Buckland & Taylor on behalf of the FLNRO, Gagnon (2012) specified the GVW and axle group load limits for MoF L-Series design vehicles in Table 4. The GVW load limits were calculated by multiplying the design vehicle GVWs by the ratio of load factors of 1.6/ 1.5 (=1.067); these calculations were checked and found to be correct. However, increasing GVW L-series load limits may cause confusion and resistance among bridge users and designers.

The calculations of axle group load limits were not checked as these were beyond the scope of this analysis, however, the single, tandem and tridem load limits were found to be consistently 20%, 37% and 40% of the GVW load limit, respectively. The author concurs with the assumption that heavy off-highway truck configurations do not feature tridem axle groups and do not need to be considered for HOH, L-150, and L165 bridges. Heavy off-highway lowbed trailers may employ 16-wheel tandem axle configurations. However, these should generate lower shear and bending moment than the corresponding bridge design vehicle because of their better load distribution. Increasing L-series axle group load limits is not anticipated to cause confusion.

Recommendation: *that FLNRO keep the GVW load limits for the L-Series bridges at historical levels but adopt the higher axle group load limits.*

LOH and HOH design vehicle GVW and axle group load limits

Gagnon (2012) estimated the HOH and LOH GVW load limit by factoring the design vehicle GVW by the LLF ratio of 1.7/ 1.5 (= 1.133). Based on analysis of truck weight data, the tandem axle load limit was taken to be 80% of the maximum design vehicle tandem axle group loading multiplied by 1.133. This was 45% of the GVW load limit for both the LOH and HOH configurations. The single axle load limit was taken to be 53% of the tandem axle load limit, and the tridem axle load limit was taken to be 110% of the tandem axle load limit.

The GVW load limits for the LOH and HOH design vehicles were checked and found to be incorrectly calculated, albeit by a small amount only. The reason for this is that the calculations of GVW and axle group load limits were based on different design vehicle GVW than currently used by the FLNRO (cattle guard design (web link)). That is, Gagnon (2012) used GVWs of 73.43 t and 114.64 t for LOH and HOH, respectively, but the current values are actually 72.375 t and 114.2 t. Table 5 presents the GVW and axle group load limits with the correct LOH and HOH GVW and axle group load limits.

Table 5: Table of maximum load limits for typical B.C. 2-girder forest bridge designs

Design Vehicle	GVW Load Limit (tonnes) [a]	Single Axle Load Limit (tonnes) [b]	Tandem Axle Load Limit (tonnes) [b]	Tridem Axle Load Limit (tonnes) [b]	Short Truck Load Limit (tonnes) [a]	Tracked Equipment Load Limit (tonnes) [a c]
L-45	41	8.5	16.0	17.5	26	32
L-60	55	11.5	21.5	23.5	28	35
BCL-625	64	9.0	17.0	24.0	33	42
L-75	68	14.5	27.0	29.5	36	45
LOH	82	19.5	37.0	40.5	46	57
L-100	91	19.0	36.0	39.5	47	57
HOH	129	31.0	58.0	n.a.	71	86
L-150	136	28.5	53.5	n.a.	70	85
L-165	150	31.5	59.0	n.a.	90	109

Notes:

a. *GVW load limits are limited to historic levels and rounded to the nearest tonne.*

b. *Axle group load limits are increased from historic levels and rounded to the nearest ½ tonne.*

c. *Tracked vehicle GVW load limits apply to concrete slab or gravel-log-stringer bridges. Design load limits for tracked vehicles on typical 2-girder forestry bridges can be increased from the limits shown by 19%.*

BCL-625 design vehicle GVW and axle group load limits

The GVW and axle group load limits for the BCL-625 design vehicle were as specified in the B.C. Commercial Transport Act and not evaluated for bridge capacity like the other design vehicles. As a result, the GVW and axle group load limits for this bridge appear to be understated and may be closer to the L-75 load limits given their similarity in short truck and tracked equipment (2-girder forestry bridge) load limits. The short truck and tracked vehicle (2-girder bridge) load limits for L-75 and BCL-625 differ by only 3 tonnes so one might expect that the GVW load limits should be closer instead of being 9 tonnes different.

Similar to MoTI posted signage, the BCL-625 axle group load limits do not allow for the wintertime weight tolerances allowed in B.C. to accommodate the parasitic weight gain from snow and ice (i.e., 2.5 t gross and 1.5 t per axle group) in B.C. With winter tolerances applied, highway legal axle group loads are 10.5 t, 18.5 t, and 25.5 t for single, tandem, and tridem axle groups, respectively. Thus, the BCL-

625 bridge load limits, as shown in Table 5, will not support log hauling trucks carrying legal highway weights during the winter. However, the BCL-625 is a very similar bridge design vehicle that is used throughout the B.C. highway system and, therefore, is capable of supporting legal gross and axle group weights with wintertime tolerances.

FPInnovations proposed higher load limits for the BCL-625 design vehicle using the logic and proportions illustrated in Gagnon (2012)'s handling of L-Series bridge design log hauling vehicles (Table 6). This approach is only appropriate **IF the trucks are carrying logs**. The approach can be summarized as follows:

- GVW load limit was taken to be the design vehicle GVW increased by the LLF ratio of 1.7/1.6 (1.067). This reflects that the design vehicle was created in S6-00 with a LLF of 1.7 for normal highway traffic but is actually operated under loading conditions better described by a LLF of 1.6.
- The tandem axle load was taken to be 37% of the GVW limit (as with all of the L-Series design vehicles).
- The single and tridem axles were taken to be 20% and 40%, respectively, of the GVW load limit (as with all of the L-Series design vehicles).

Table 6: GVW and axle load limits for BCL-625 carrying log hauling traffic

	GVW Load Limit (tonnes)	Single Axle Load Limit (tonnes)	Tandem Axle Load Limit (tonnes)	Tridem Axle Load Limit (tonnes)
Calculated new load limits	68	13.5	25.0	27.0
Difference from L-75	-5	-1	-2	-2.5
B.C. legal highway weights with winter tolerances	65	10.6	18.5	26.5
Proposed load limits	**68**	**13.5**	**25.0**	**27.0**

Upon inspection, the axle group load limits appear reasonable with differences from the corresponding L-75 load limits ranging between 1 and 2.5 tonnes. If utilised, these axle load limits would be more than sufficient to carry highway legal gross and axle group loadings with winter weight tolerances. A decision to increase the GVW load limit to something in excess of 64 t (63.5 t), however, may create confusion because of the widespread use of this bridge design for highway legal traffic.

Recommendation: *Given that the BCL-625 bridge design is commonly used on resource roads utilized by highway traffic, and this traffic typically has more variable gross and axle group weights than log truck traffic, it is recommended to leave the load limits unchanged from those shown in Table 5.*

MoF L-60 design vehicle GVW and axle group load limits

The axle group loadings for this bridge appear sufficient for many log hauling truck configurations except for the tridem axle group load limit. As with the BCL-625 load limits, the tridem axle group load limit is not high enough for 26.5 t legally loaded tridem groups (with winter tolerance). Fortunately, there are few of these bridges in-service. If FSR users wish to use them for carrying legally loaded log hauling trucks with tridem axle groups, then the L-60 bridges should be professionally load rated and this will likely lead to higher load limits for individual bridges. The bridge design is of limited usefulness for today's truck configurations and construction of new L-60 bridges is not recommended.

MoF L-45 design vehicle GVW and axle group load limits

The GVW and axle group load limits for this bridge in Table 5 are too small to accommodate most legally loaded log hauling trucks but would be sufficient for a variety of short trucks and tracked vehicles. The bridge, therefore, is of limited usefulness and construction of new L-45 bridges is not recommended. McClelland (2012) notes that road users are likely to ignore the posted limit of these bridges or not haul over them at all.

It is anticipated that in-service L-45 bridges will need to be individually load rated and posted accordingly in which case the load limits may increase by 9% (with a reliability index β of 3.25). Further, many of these bridges were over-built and load rating is likely to identify this.

Load rating existing forest bridges

Section 14 of CAN/CSA S6-06 provides direction to bridge engineers conducting a load rating of an existing bridge. Knowing details about the traffic loading and the as-built bridge condition the engineer may be justified in adopting smaller live load factors for the determination of bridge capacity. As a result, considerably higher GVW and axle group load limits than shown in Table 5 may be applied to the bridge.

Communicating bridge load limits

Adoption of the load limits in Table 5 will increase the ratings of new forest bridges. These changes and the reason for them need to be communicated to Road Use Permit holders and other resource road users. This may best be done through an engineering bulletin posted on the Engineering Branch website, letters sent to Road Use Permit holders, trade magazine articles, and presentations given to Road Safety Committees around the Province.

This initiative provides an opportunity for the Ministry to update its bridge load rating policy. McClelland (2013) states that "essentially [the FLRNO] could use the [Table 5] values as default bridge design load ratings but could allow engineers to increase the loadings for specific truck styles on designated roads provided the requirements of Section 14 of CAN/CSA-S6-06 are met." This initiative also provides a process to introduce the LOH and HOH design vehicles to forest bridge designers and to resource road users.

Sign configuration

A load rating sign at the commencement of an FSR is intended to show the load limitations for the road network. This signage would be based on the design vehicle limits and reflect the findings of Table 5. In the case that a mixture of bridge designs exists on a FSR network then the load road rating should consider all of these and base the road load limit on the minimum load limits for GVW and axle groups. For example, a network with multiple L-100 and LOH bridges, for which the design load limits still apply, should be posted with the GVW and short truck GVW from the LOH design but axle group load limits from the L-100 design (Figure 5). The tracked equipment design would be 44 t as this is the minimum for both bridge designs.

Design Vehicle	**GVW Load Limit (tonnes) [a,c]**	**Single Axle Load Limit (tonnes) [b]**	**Tandem Axle Load Limit (tonnes) [b]**	**Tridem Axle Load Limit (tonnes) [b]**	**Short Truck Load Limit (tonnes) [a]**	**Tracked Equipment Load Limit (tonnes) [a]**
LOH	**82**	19.5	37.0	40.5	**46**	**44**
L-100	91	**19.0**	**36.0**	**39.5**	47	**44**

Figure 5: Road load ratings may comprise GVWs and axle group load limits from more than one bridge design.

Bridge capacity signage should consider its application; road load rating is not necessarily required to be the same as the posting of a bridge that has been identified as having sub-standard capacity. If a bridge near the start of a mainline (FSR) is down-rated and all traffic has to cross that bridge to access the FSR network, the road load rating for the entire network should be reduced to be the same as the down-rated bridge. If a bridge is down-rated but it does not restrict access to most of the FSR network (e.g., it is located on a spur road or there is a bi-pass route), then the load road rating for the network will be higher and the load limits for the down-rated bridge need to be signed separately.

Sign formats

Bridge capacity signage quantifies the loading limits of the structure. The vehicle operator must read the sign to compare what he estimates his vehicle's loading is against the stated capacity in order to assess the risk of crossing. To not adhere to the posted loadings is in violation of the Forest and Range Practices Act. In spite of that vehicle operators may choose to ignore bridge capacity signs for a variety of reasons, including:

- The sign is confusing or ambiguous. For example, if the sign does not appear to include information about the operator's vehicle type.
- The load limits are less than the capacity of the operator's vehicle but the operator perceives that there is a low risk of bridge failure, and the cost of compliance is more than the perceived cost of crossing the bridge.

- The load limit is judged too restrictive or conservative. For example, the L-165 load limit of 85 t for given in Table 4 is less than an entire class of yarders commonly used on the B.C. Coast; however, it has been common practice to cross L-165 bridges with heavy yarders.
- The operator doesn't know his/her own vehicle's loading. This is especially likely with off-highway vehicles not equipped with on-board weigh scales. It may also occur with highway trucks that don't commonly cross highway weigh scales or those not equipped with on-board weigh scales. Note that most log hauling trucks in B.C. are equipped with on-board weigh scales that display axle group weights.

In order to make a bridge capacity sign understandable and easily read, it is recommended to utilize already standardized sign formats found in CAN/CSA-S6-06 (Anonymous 2006), the size, shape, colouring, materials and font formats defined in the FLNRO engineering manual (Anonymous 1999) and universal symbols rather than words where appropriate. CAN/CSA-S6-06 offers several standard sign layouts. Figure 6 illustrates these sign formats.

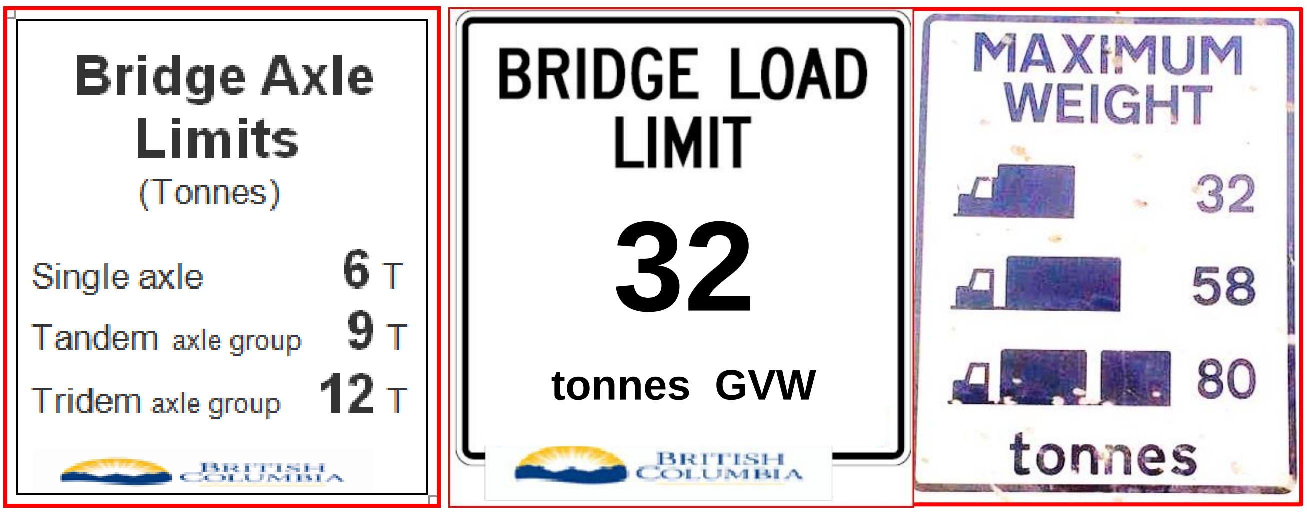

Figure 6: Highway bridge capacity sign formats (axle load limits, overall load limit, triple posting).

The FLNRO should adopt a sign format that is unambiguous and can be used to represent all current and anticipated future vehicle configurations on FSRs. Anonymous (2010) specifies load rating sign formats for down-rated structures, however, the signs list only a GVW value.

Standard ministry bridge load posting sign specifications (including text size, font, sign size and shape, sign material, colour, etc.) should be developed. Use of universal symbols and abbreviations will help make the signs easier to read and understand. Use the word GVW to represent total vehicle load limit. Use black circles to represent the wheels of the axle groups if posting axle group load limits—one wheel for a single axle, two wheels for a tandem axle group, three circles for a tridem axle group. Use truck silhouettes without wheels to represent vehicle classes (two trailer unit, one trailer unit, short truck). Truck silhouettes without wheels are inclusive of all possible axle configurations, and easier to read than if shown with wheels. Use a rectangle with rounded ends and multiple square protuberances to represent a tracked vehicle. Load limit values should be shown as t or tonnes; use of capital T may lead to confusion with imperial tons.

The sign should also show the issuing authority and the date of issue. These can be displayed with a FLNRO and Provincial logos, and a small font for the date located near the bottom of the sign. It may be advisable to also include a phone number from which load limit information can be obtained (e.g., an FLNRO or Licensee contact number).

Recommendation: *Ministry develop standard signage for bridge capacity with a sign (Figure 8) that combines GVW, axle group weight load limits, short truck GVW, and tracked equipment GVW Alternately, if axle group load limits are less than legal limits, show only a single GVW limit that is the lesser of the short truck GVW and tracked equipment GVW*

Signs for posting bridge design vehicle load limits

L-45 bridges: As mentioned in the preceding discussion, L-45 bridge load limits in Table 5 are too small to accommodate most legally loaded log hauling trucks but would be sufficient for a variety of short trucks and tracked vehicles. Rather than show load limits that are less than legal limits, it may be preferable to show a single bridge load limit based on the lesser of the 25.5-t short truck GVW and the 25-t tracked equipment GVW (Figure 7). As the 25 tonnes is much less than the weight of any loaded log hauling vehicle this should discourage these vehicle from using the bridge.

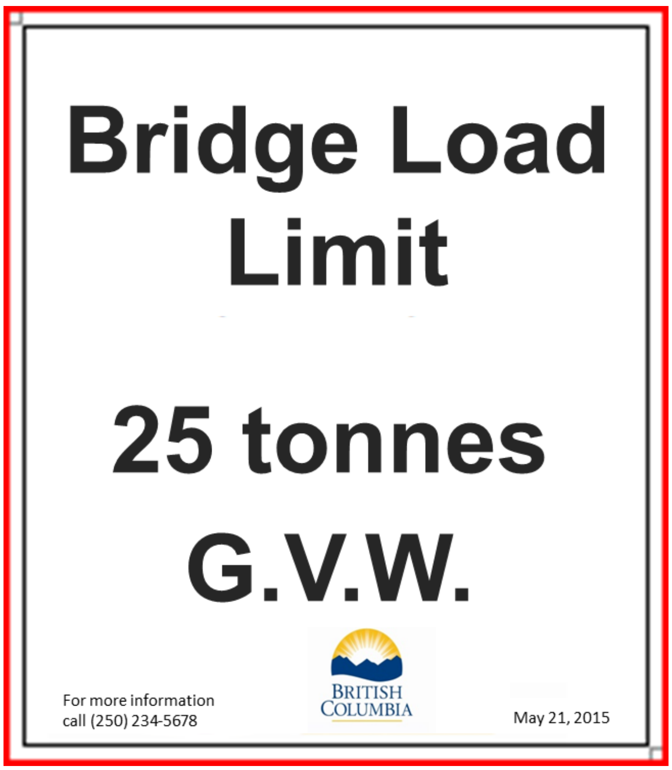

Figure 7. Suggested L-45 road network load limit sign based on the lesser of the short truck and tracked equipment load limits.

It is anticipated that many L-45 bridges will be load rated and, in so doing, may feature higher load limits than the default design vehicle load limits in Table 5. If the new axle group load limits exceed legal axle weights, then the L-45 capacity sign should include GVW, axle group weight load limits, short truck GVW, and tracked equipment GVW

L-60 bridges: As mentioned in the preceding discussion, the 23.5-t tridem axle load limit shown in Table 5 is less than the current tridem axle group legal limit of 26.5 tonnes (with 1.50-t winter tolerance). This may lead some operators of trucks with legally loaded tridem axle groups to ignore the bridge capacity sign because their truck meets all of the other load limits. There are strategies that could be pursued by FLNRO to increase the tridem axle group load limit to 26.1 tonnes or beyond. Therefore, it is suggested that the bridge capacity be represented with a full posting (GVW, axle group weight load limits, short truck GVW, and tracked equipment GVW).

L-75 to L-165 bridges: It is suggested that these bridge capacities be represented with a full posting (GVW, axle group weight load limits, short truck GVW, and tracked equipment GVW). This sign could be as shown in Figure 8 provided that all of the bridges on the network are typical 2-girder forest bridges. If there are both 2-girder and slab or gravel-over-log-stringer bridges then both load limits for tracked vehicles should be shown on the sign or just the lesser of the two.

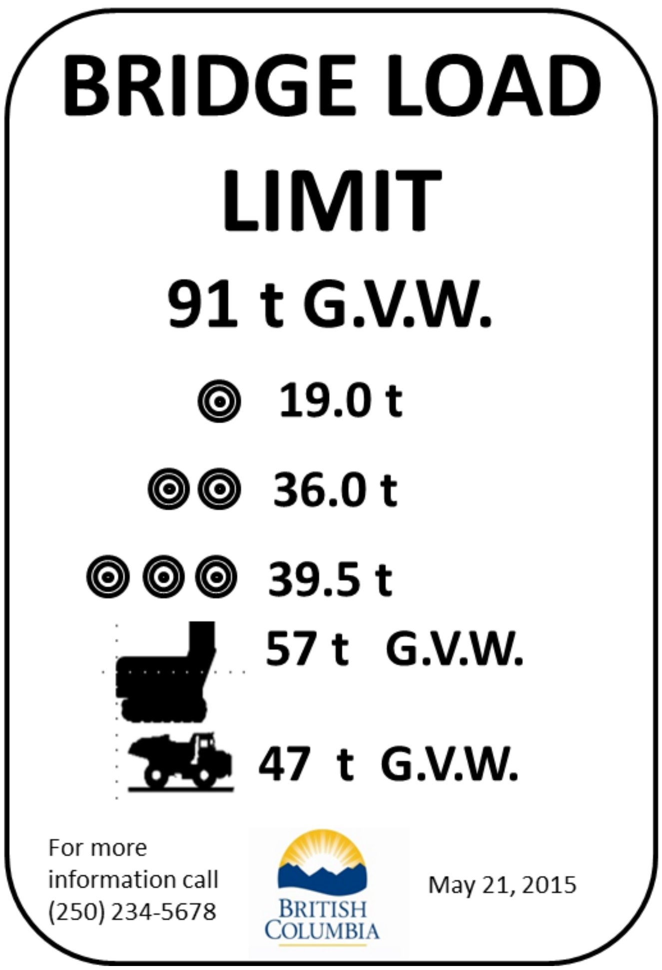

Figure 8. Suggested full posting road load sign for an L-100 FSR network. Use the same full posting format for L-60, BCL-625, L-75, LOH, HOH, L-150, and L-165 networks.

Down-rated bridges: A load rating sign for a bridge with a sub-standard capacity, depending on the severity of the reduced capacity, may require less information. Bridges that cannot support common truck configurations with legal highway loadings should be posted more simply so that drivers are not confused or frustrated when their trucks are partially but not fully compliant. An example of this is the L-45 design vehicle in Table 5 which is unable to support trucks with legal tandem or tridem axle loads.

Some forest companies report a practice of posting bridges to 5 tonnes that have been load rated to 50 tonnes or less (the lowest GVW limit of their log hauling trucks). However, this practice unfairly prevents short trucks, tracked vehicles, and some common but non-forestry, legally loaded, tractor/semi-trailers from using the bridge. Legally loaded 5-axle tractor/ tandem semi-trailers can weigh as little as 40 tonnes and 6-axle tractor/ tri-axle trailers can weigh 49.1 tonnes. The chief consideration when choosing to use a simple sign for a down-rated bridge should be whether the down-rated capacity precludes the use of legal axle weights by road users. If it does not, post the bridge with the various load limits identified in Figure 8. If it does, post the bridge with a simple GVW limit sign reflecting the lesser of the short truck or tracked equipment load limit (Figure 7). Engineering Bulletin 2 (Anonymous 2010) specifies sign formats for this which also may be acceptable (Figure 9).

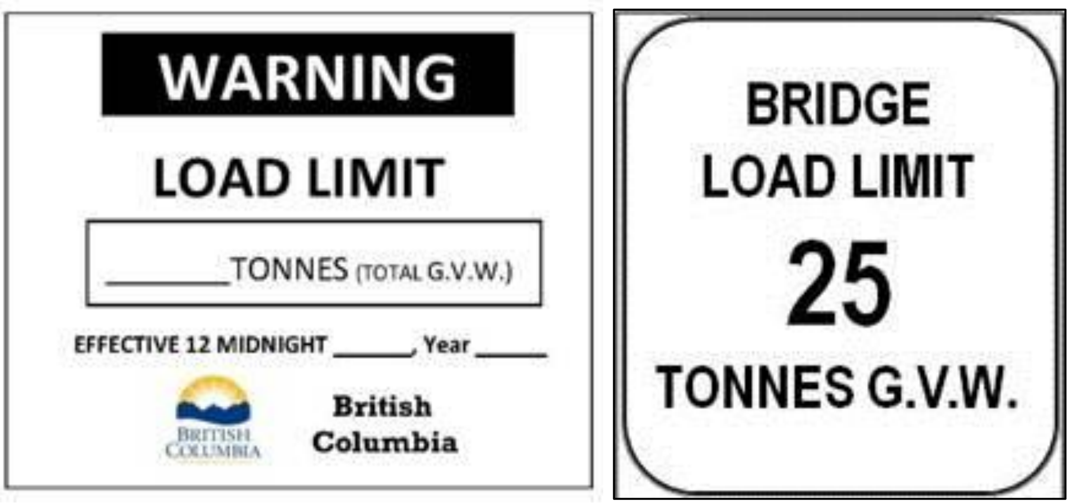

Figure 9: Simple sign formats for down-rated bridges.

ROAD LOAD RATING CONCEPT EVALUATION

Stakeholder survey

FPInnovations solicited feedback on the road load rating concept from a cross section of stakeholders: 5 forest bridge design consultants (Associated Engineering (B.C.) Ltd., Stonecroft Project Engineering, AllNorth Engineering, Onsite Engineering Ltd., and Caliber Bridge and Design Ltd.), the B.C. Forest Safety Council, the B.C. Ministry of Transportation and Infrastructure (MoTI), the largest B.C. forest licensees (West Fraser Mills, CANFOR, Tolko Industries, Western Forest Products and TimberWest), the FPInnovations' B.C. extension officers, a transportation consultant working for Aero Transport, and members (trucking contractors) of the B.C. Log Truck Technical Advisory Committee.

Feedback from stakeholders:

- Road load rating concept makes sense and is a timely idea given the impending rapid industrial development projects that will utilize FSRs.
- Has there been an increase in failures and is this concern quantifiable? Is this concern just limited to a few areas of the Province? Does the road load rating initiative address the root issue? Is it necessary to add a process as a one-off when the Resource Road Act is being developed to handle resource road use, in general?
- This additional process will mean extra costs for maintaining signs but isn't likely to change most overloading behavior. Anyone who truly cares will check on the bridges in the network if they have an unusually large load before they start. The rest will use the road regardless of the sign.
- Explaining bridge capacity ratings will require a pretty elaborate sign. The sign may change by season or might cause mass confusion. It may be better to put a default rating on all bridges unless otherwise posted (similar to how it is addressed now).
- The road load limits should show a GVW for both two trailer semi-trailers and one-trailer-semi-trailers as is done with a triple posting sign (in CAN/CSA-S6-06). Listing one GVW that applies to all tractor semi-trailer configurations may be confusing.
- Road load rating concept might better be called a <u>road network load rating</u> concept
- A general load rating sign for the FSR network should be located before the truck has committed to traveling on the FSR and be in close proximity to a place where trucks exceeding the rating can turnaround. However, the point of commencement (PoC) of an FSR may be already filled with signs and drivers may not notice one more. Further, some safety incidents have occurred at PoCs when drivers stopped to read signs. If the PoC already has numerous signs, consider locating the sign on its own somewhere further along the FSR and near a turnaround opportunity.
- It may be challenging to post signs at all entrances to a FSR network given the interconnectedness of some networks with adjacent roads and networks. This is especially prevalent in the Interior. This situation may require numerous road network load rating signs.

- It is sometimes difficult to know where FSRs end and other tenure roads commence. It needs to be clearly signed to which parts of the road that road load ratings apply. It would be useful to delineate this in the Road Use Permit Agreement.
- If the load limit is restricted after some distance up an FSR, consider making the road network load rating sign say that the first X km of the FSR has one capacity and beyond that the FSR has a reduced capacity. A sign with the reduced road network load limit also should be located at a turnaround opportunity before the first restricted bridge. This information should be included in the road use permit and shared with the road safety committee.
- This initiative will be straight forward if only for FSRs but may become more complicated when including all of the other tenure roads.
- When adding information to a Road Use Permit Agreement it may be preferable to say merely that “all brides are built to (the minimum rating such as, L75) unless otherwise posted.” Avoid giving specifics for individual bridges as this would not achieve all the objectives that the initiative is looking for.
- It is doubtful whether all drivers will know their axle group weights on all trips. Some on-highway and off-highway vehicles using FSRs are not equipped with on-board weigh scales and may not cross a weigh scale prior to travelling on the FSR.

Based on the feedback received, FPInnovations believes that the FLNRO concept of posting each FSR network according to its minimum bridge load limit appears to be a sound concept. The concept is similar to that used by the B.C. MoTI in that it builds all infrastructure to a minimum structural standard and, rather than posting each structure, informs users of public roads what the load limits are through its weights and dimensions regulations. Exceptions to this include when a bridge is down rated (the capacity is posted on the bridge and on signs on major routes leading to the structure), and when higher than normal capacity infrastructure has been created (the route is posted with ‘heavy haul route’ signs.

Where there are numerous entrances to a FSR network, the District Manager should determine whether the neighbouring networks and roads have the same road load as the subject FSR network. If so, it may not be necessary to post all possible entrances to the subject FSR network and this should be discussed with the local road safety committee(s).

Road Use Permit

The Road Use Permit may provide a useful way to inform road users about bridge capacities (road load limit) of each FSR. However, the FLNRO should not rely on this document alone to inform road users. Not all vehicle operators will be aware that there is a Road Use Permit, let alone what it contains. Some industrial users are not subject to the Forests and Range Practices Act and these road users should be informed about the bridge capacities (road load) through other means (e.g., cutting permits, construction contracts, B.C.TS bidding information, road signage, and local road safety committees).

Road Use Permits include vehicle weight and size limitations, when necessary, and, therefore, are an appropriate place to provide Permittees and other road users with information about a road load limit. Information about the road load limit could be included in section 2.00 Conditions of Use. A road load clause might read something like:

This FSR and its branch roads listed in Schedule "A" have a minimum bridge capacity (a road load) unless specifically noted otherwise. The specific load limits for this FSR and named branch roads are listed in Schedule "A". The Permittee or other road users may apply to the FLNRO District Manager for an overload permit to move a vehicle exceeding this road load limit.

In Appendix A make the following additions:

In the first table in Schedule "A", add a column to the right of column with FSR Branch No. and in this indicate the road load limit on a km to km basis.

FSR Name/ Project Number	FSR Branch No.	**Road Load Limit (refer to the load limit table in additional clause section for further details and exceptions)**	Section to be Used		If Off-Highway, Indicate Vehicle Size A,B, or C From Next Section	FLNRO USE ONLY Road Use Permit holder required by District Manager to maintain the FSR Name/ telephone number
			Km to Km			
Greenwater	-	**68 t GVW**	0	45		
Greenwater	1000	**68 t GVW**	0	4		
Greenwater	1000	**29 t short truck GVW**	4	22		

A table of road load limits, and exceptions, based on Table 5, could be included as an additional clause to Schedule “A”.

Table: Road Load Limit Information

Design Vehicle	GVW Load Limit (tonnes)	Single Axle Load Limit (tonnes)	Tandem Axle Load Limit (tonnes)	Tridem Axle Load Limit (tonnes)	Short Truck Load Limit (tonnes)	Tracked Equipment Load Limit (tonnes)	
						2-girder forest bridges	Slab type and gravel-over-log-stinger bridges
L-75	68	14.5	27.0	29.5	36.0	53	44

Exceptional bridges*: One bridge within the Greenwater FSR network currently is down-rated to less than the road load limit. The single lane span at 4 Km on 1000 Road has been down-rated by FLNRO bridge engineers to a load limit of 29 t.*

CONCLUSIONS

FPInnovations conducted a technical check of B.C. forest bridge design load limits that had been proposed to the FLNRO by Buckland & Taylor Ltd. and SNT Engineering Ltd. These load limits were found to be correctly calculated in general; however, a minor error was found with the GVW and axle group load limits for the LOH and HOH design vehicles and the correct values were calculated. In addition, the load limits for tracked vehicles were found to be too conservative. Less conservative load limits were calculated after consultation with local bridge design experts; load limits for tracked vehicles walking over slab type and gravel-over-log-stringer bridges were also estimated. The methodology for estimating load limits involved assuming appropriate values for live load factors (live load allowance, dynamic load allowance, live load distribution factor). This analysis investigated these assumptions and found them, in general, to be reasonable. Despite the higher estimated design truck GVW load limits, it was recommended to maintain the historical GVW limits for the MOF L-Series bridge designs in order to avoid confusing bridge users and designers. It was recommended to adopt the new axle group load limits for the L-Series bridges.

The load limits proposed for each forest bridge design were evaluated in light of current log hauling truck configurations. The L-45 bridge design is not sufficient for legally loaded vehicles and so using this type of bridge may lead to confusion; it is recommended that the default load limit for these bridges be expressed only in terms of short truck and tracked equipment GVWs. The L-60 bridge design vehicle load limits specify a tridem axle load limit less than legal loading and this may cause confusion; it is recommended that FLNRO investigate alternatives to increase this limit. The BCL-625 bridge design GVW and axle group load limits were not estimated and instead legal weights were adopted as bridge load limits. This approach appears to underestimate the capacity of BCL-625 bridges, however, given that highway traffic sometimes uses these bridges, and increasing the stated design capacity may cause confusion, it was recommended not to change the load limits.

Adoption of the proposed bridge design load limits will clarify GVW and axle group load limits of new forest bridges. These changes and the reason for them need to be communicated to Road Use Permit holders and other resource road users. This initiative also presents an opportunity for the FLNRO to update its bridge rating methodology and to introduce the LOH and HOH design vehicles to forest bridge designers. Load limits for constructed bridges may be increased from those presented in this report for new bridge designs.

In order to make a bridge capacity sign understandable and easily read, it is recommended to utilize already standardized highway bridge sign formats, pattern the signs on the size, shape, colouring, materials and font formats defined in the FLNRO engineering manual, and employ universal symbols rather than words where appropriate. Simple sign formats were recommended for use specifically with L-45 bridges and for down-rated bridges that can’t support legal axle weights; and, a general full posting sign was recommended for use with the other bridge designs.

A stakeholder survey was conducted to ascertain the acceptance of the road load concept and to identify potential barriers to its use. This survey indicated general acceptance of the concept. A number of operational issues were identified (e.g., road load signs need to be located near turnarounds) and potential solutions offered.

Based on the stakeholder feedback and project discussions, FPInnovations believes that the FLNRO concept of posting each FSR network according to its minimum bridge load limit appears to be a sound concept.

Part of the communication strategy for introducing the road load concept should include adding specifics to the Road Use Permit. Some language for a clause and table additions are suggested.

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APPENDIX 1. LIVE LOAD ADJUSTMENT FACTORS USED FOR THE ANALYSIS

Design Vehicle	Design Live Load Factor	Dynamic Load Allowance	Distribution Factor
L-45	1.60	30%	0.69
L-60	1.60	30%	0.69
BCL-625	1.60	30%	0.69
L-75	1.60	30%	0.69
LOH	1.60	30%	0.69
L-100	1.60	30%	0.69
HOH	1.60	30%	0.69
L-150	1.60	30%	0.69
L-165	1.60	30%	0.69
Short truck	1.60	30%	0.69
Tracked on 2 girder forestry bridge	1.30	30%	0.55
Tracked on slab or gravel-over-log-stringer bridge	1.30	24%	0.23
Tridem axle	same as design vehicle	30%	0.69
Tandem axle	same as design vehicle	30%	0.69
Single axle	same as design vehicle	30%	0.69

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